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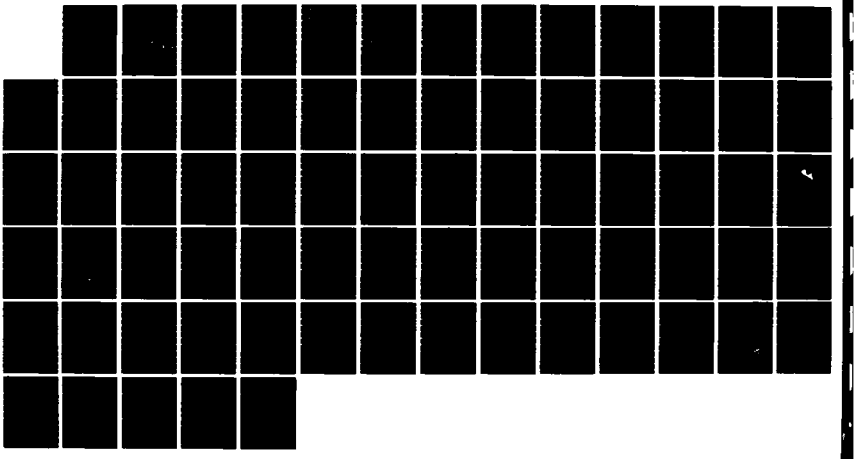

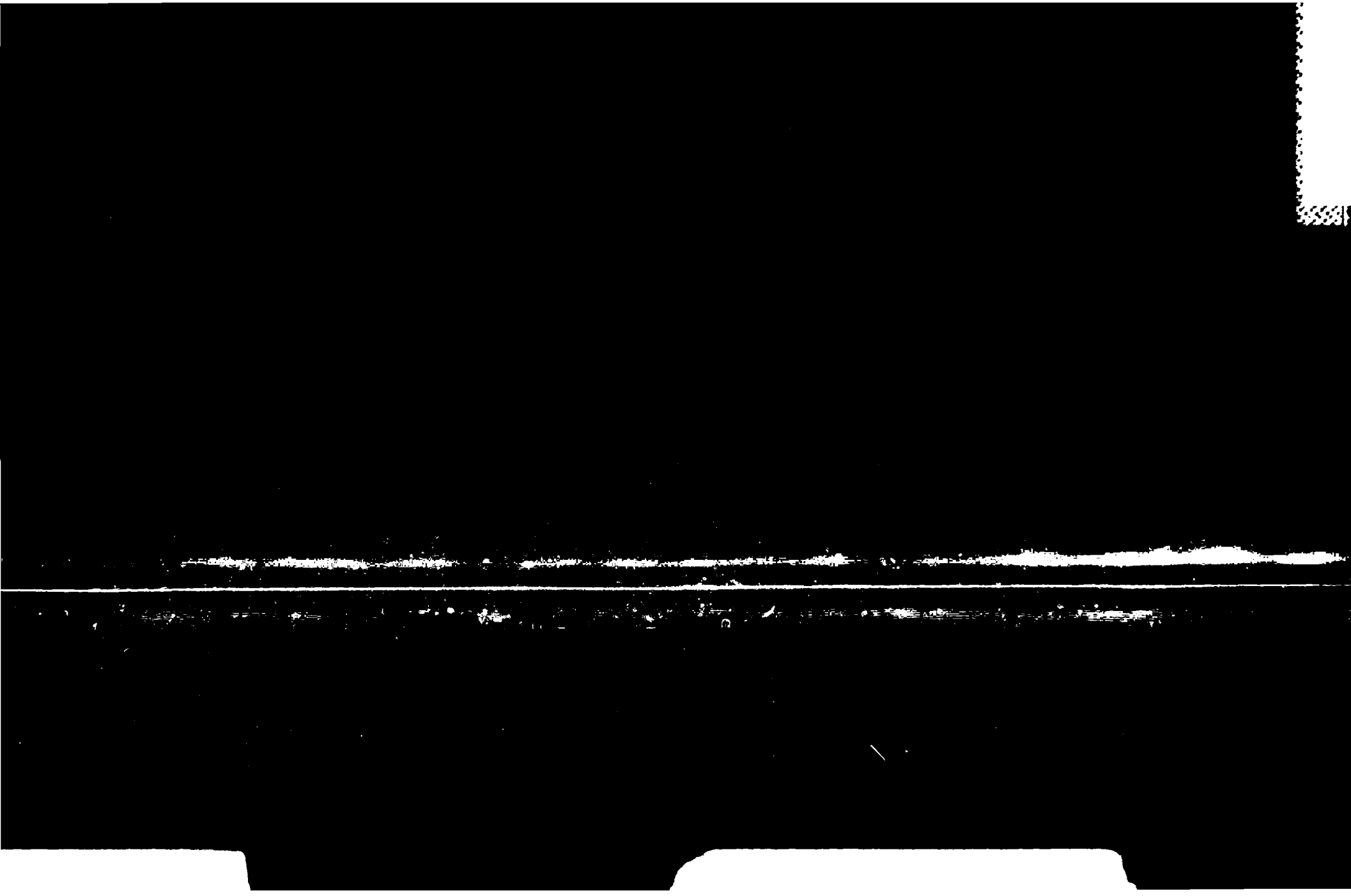

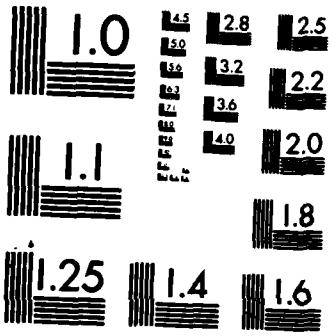

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European Scientific Notes (ESN) is a monthly publication with brief articles on recent developments in European scientific research. The publication is not intended to be part of the scientific literature. The value of ESN articles to Americans is to call attention to current developments in European science and technology and to the institutions and people responsible for these efforts. ESN authors are primarily ONRL staff members. Occasionally articles are prepared by or in cooperation with staff members of the USAF

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Commanding Officer ..... CAPT M.A. Howard, USN
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BEHAVIORAL SCIENCES

BIOLOGICAL SCIENCES

COMPUTER SCIENCES

PHYSICS

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BEHAVIORAL SCIENCES

TOWARD A COGNITIVE PSYCHOLOGY OF PERSONALITY ASSESSMENT?

by Richard E. Snow. Dr. Snow is the Liaison Scientist for Psychology in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until September 1985 from Stanford University, where he is Professor of Education and Psychology.

The measurement of characteristics of human personality has not been an area full of major advances in recent decades. For the practical purposes of selection or classification in the military and in industry, and for research in many areas of psychology and education, one typically must buy some sort of conventional personality inventory or questionnaire, or build one from scratch, and hope to capture some bits of useful empirical validity.

Part of the problem has been the absence of an adequate theory of individual response to personality measures. Some attempts to formulate cognitive processing models of such response have been building up slowly in recent years, focused mainly on the analysis of the subjective meaning structure of inventory items (see, e.g., Cliff, 1977; Cliff, Bradley, and Girard, 1973; De Boeck, 1978, 1981; Rogers, 1974). Now, however, some new results from a different tack may offer something of a breakthrough; at least they open up an important line for innovative research. They also provide a nice example of benefit through cooperation between university-based research and applied military research.

In brief, the new finding is that the validity of personality measures may be substantially increased when a free-response self-description instrument is administered first in a battery including other, conventional instruments. The interpretation is that free response first activates a person's recall of relevant information from personal knowledge structure; in other words, the content of conscious or working memory is enlarged and intensified in a state of free, self-focused attention. The effect is to improve the validity of the person's responses both to free-format instruments and to the typically fixed-format inventories and other instruments that come afterward. When not preceded by free recall, conventional inventories, rating scales, and questionnaires may appear circumstantial, so response to them may be impulsive and superficial and hence less valid.

Willem Claeys, Paul De Boeck, and their colleagues at the University of Leuven teamed up with Arnold Böhrer of the Belgian military's psychological research center to conduct a series of three studies comparing personality assessment methods (Claeys, De Boeck, Van Den Bosch, Biesmans, and Böhrer, unpublished). The aim was to see if a free-response self-description instrument might do as well as two more conventional fixed-format measures. The free self-report asked the respondent to: "describe your personality, as completely as possible, listing ten adjectives. Do not say how you want to be, but say how you really are. Try to use words of common usage." One fixed format instrument was a traditional inventory, in which respondents indicated the degree to which various descriptive items applied to them; it contained scales of items representing personality trait dimensions such as "extraversion," "agreeableness," "conscientiousness", and "neuroticism." The other fixed format consisted of one-item self-judgments using scales comparable to those of the inventory, including adjectives such as "lonely," "sociable," "punctual," and "tense," to correspond to the inventory dimensions.

In the first study, using a sample of male high school students, the three forms of measure showed relatively high correlation with one another (r about 0.60) and relatively low correlation with a criterion of behavioral ratings obtained from parents and friends (r about 0.20). The striking difference in validity was found, however, when the sample was divided into those who received the free-format first, followed by the fixed-formats versus those who received the opposite order. With free-format first, the validity of all three instruments was higher, whereas the opposite order showed little validity. A second study, again with high school students, replicated the effect and removed the competing hypothesis that any short introductory instrument, not free recall particularly, would produce the validity difference.

Some of the results of these two studies are shown in Table 1, which also includes data from the third study, conducted in a military officer selection context. These last results again show the validity difference, though here it is attenuated by several factors that operate in this context and not in the university-based research.

Table 1

Correlations of a Combined Behavioral Criterion With Three Self-Report Personality Assessment Methods In Free/Fixed and Fixed/Free Order Conditions

		Free/Fixed Order			Fixed/Free Order		
	Trait Dimension	Fixed Inventory	Fixed 1-Item Judgments	Free Description	Fixed Inventory	Fixed 1-Item Judgments	Free Description
Study 1	Extraversion	0.52	0.41	0.46	0.14	0.27	0.07
	Agreeableness	0.46	0.49	0.52	-0.25	0.32	0.15
	Conscientiousness	0.52	0.41	0.54	0.33	0.23	0.25
	Neuroticism	0.55	0.38	0.56	0.10	0.04	-0.13
	Average	0.51	0.42	0.52	0.08	0.22	0.08
Study 2	Average	0.41	0.34	0.41	0.25	-0.06	0.05
Study 3	Achievement motivation	0.31			0.10		
	Facilitating anxiety	0.28			0.27		
	Debilitating anxiety	0.21			0.21		
	Social anxiety I	0.21			0.18		
	Social anxiety II	0.31			0.28		
	Self-confidence	0.39			0.30		
	Average	0.29			0.22		

Notes:
1. Study 3 used a different inventory method, no 1-item judgment method, and no free description method in the fixed/free condition, so correlations for free description are not shown; negative anxiety scales are reflected to eliminate negative correlations.
2. N=24 and 19 per order condition in studies 1 and 2 respectively.
3. N=256 and 365 in free/fixed and fixed only conditions in study 3.

In the Belgian armed forces, officer candidates go through a 2-day selection procedure involving various cognitive tests, personality inventories, physical skill demonstrations, and an observation measure of leadership in a group. They are then selected on the basis of these measures for the training program. Study 3 was created by inserting the free response task ahead of the personality battery (composed of scales differing from those of the previous studies) for one large group of candidates but omitting it for another; free response could not be added after the battery for the latter group due to practical constraints. The leadership observation served as the criterion. Here, then, a rather different behavioral criterion and different personality battery were used in a more complex assessment context and among respondents motivated to present themselves in a favorable light. Some attenuation was to be expected, but it is notable that two personality dimensions--the achievement motivation and self-confidence scales--still showed a validity differential that deserves closer examination in further research.

Deserving of much further research also is the possibility that the personal knowledge structure that individuals bring to bear in self-reports of personality can be activated by free recall to increase the validity of ensuing reports. The rationale for conventional inventories is that individuals will reveal their personalities by recognizing themselves as fitting in some degree statements composed by researchers. The approach essentially ignores the individuality of personal self-concepts, as well as the possibility that such self-knowledge may not routinely be consciously available. Free response, on the other hand, allows individuality of response and may also provide a more intensive conscious search of stored personal knowledge. The distinction is parallel to the recognition versus recall distinction in memory research, about which a great deal is known in cognitive psychology.. It is also to be noted that the free recall form of reporting personal conceptions is akin to the phenomenographic methods used in Swedish research to study learner's conceptions of their own learning in science (see next article). The coordination of these three lines of research may produce a richer and more integrated view of the cognitive psychology of personal knowledge, as well as practical improvements in assessment technology.

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PHENOMENOGRAPHY AND INTELLIGENCE: A SWEDISH APPROACH TO THE PROBLEM OF PERSONAL KNOWLEDGE

by Richard E. Snow.

A central goal for cognitive science is an improved theory of the acquisition, organization, and use of knowledge--particularly the sorts of complex knowledge needed to solve problems in science. Advances in the psychology of human intelligence, in the development of artificial intelligence, and in the design of instruction at all levels of science education depend on it.

In a previous article in this series, a critique of US research arising from Dutch work on physics problem solving was noted (*ESN* 38-2: 63-66 [1984]). J.J. Elshout and his coworkers at the University of Amsterdam have taken the position that novice problem solvers are not the "empty experts" assumed in much US research. Rather, novices struggle through beginning and intermediate levels of learning using a disorganized, incomplete, bookish, and impressionistic knowledge base that contains substantially incorrect ideas. Acquisition and organization of new knowledge must occur in this cognitive context--substantial unlearning and relearning, as well as new learning, is required. The Dutch research aims to build an intelligent coach for physics learners in which a computer model of their chaotic arrays of partial and incorrect ideas can be built up through interaction with the learners; the model can then serve a diagnostic and tutorial function during further instruction. Protocols reflecting novice verbal and procedural activity during problem solving are collected, which the computer model attempts to simulate. So far in Amsterdam, the model approximates the behavior of intermediate-level learners, but it does not yet work well with the more erratic novices.

Part of the problem may be our lack of understanding of the nature of personal knowledge. At the University of Göteborg, Sweden, Ference Marton and his coworkers have taken a rather different approach to the study of personal knowledge among science students (and others). Their results may complement the Dutch work by providing rich descriptions of the content of student knowledge and of the qualitative changes in such knowledge that occur through learning, or fail to occur, in particular situations. The approach is called "phenomenography" because it combines the emphases of European phenomenological psychology with a dedication to systematic description of concrete cases (Marton, 1981). It represents a significant critique of mainstream US psychology even while it dovetails with growing attempts in US and UK work to reach richer descriptions of student mental life by using personal reports in addition to the typical objective measures of knowledge and skill acquisition.

The uniqueness of the Swedish work lies in its concern for *what* students understand and *how* they understand it at any given point, rather than *how much* students have learned. It seeks to discover sets of qualitative categories by which to describe student conceptions of various aspects of reality. Learning is then defined as a transition between these phenomenographic categories. Ultimately, with enough such research, one can imagine building a "phenomenography of physics," incorporating all the systematic categories that describe people's interpretations of physical phenomena. Similarly a phenomenography of mathematics, corresponding to systematic knowledge about the ways people understand and use mathematical concepts, or a phenomenography of geography, or of economics might be built.

The contrast between the phenomenographic approach and that of mainstream

psychology is, at base, one of philosophical and theoretical perspective. In brief, most psychological research on intelligence, knowledge, learning, and the like takes a *first-order*, observational perspective, attempting to describe these aspects of the world in a manner formally similar to the sorts of descriptions found in the physical sciences. So, for example, some aspect of the learner is observed and measured, some aspect of the learner's world is observed and measured, and the two are related within an explanatory framework imposed by the observer. The observer may also manipulate the learner's world experimentally to examine whether effects on this relation conform to hypotheses in the framework. Personal reports from the learners themselves may even be collected to help explain experimental results, but they are not viewed as the primary data. The aim is to establish principles about basic mechanisms of learning that can be generalized beyond the immediate observations to all learners, all contents, and all learning contexts, or at least to broadly defined populations of learners, contents, and contexts.

Marton and the Göteborg group, on the other hand, take a *second-order, experiential* perspective, aiming to describe people's experience of these aspects of the world within their personal points of view. In the case of learning, the concern is with the content, context, and awareness of learning as observed by the learners themselves. As Marton and Svensson (1979) characterize it:

"Learning always occurs naturally in a context . . . . An experiential perspective means . . . that instead of describing the context in . . . researchers' categories defined in advance we try to find the categories in terms of which the students interpret the context . . . not described independently of the learners but rather through their eyes. The description thus refers to the way in which the students relate themselves to the situation" (p. 473).

". . . Learning always has a content as well. There is obviously no learning without a content. The learner's construction of meaning . . . of the content is the very heart of the learning experience. We consider the finding and describing of conceptions (meanings) of fundamental aspects of various learning materials to be one of the main tasks of research into student learning" (p. 473).

"Lastly, not only is there a consciousness of the content in the learner but there is a consciousness of his being conscious of it as well . . . . The learner's experience of the act of learning" (pp. 473-474).

Consider the sort of problem that might appear on a typical achievement test in physics:

In an experiment with a ball, it is found that when the ball falls, it is affected by the air with a braking force F which is proportional to the velocity of the ball v. In other words, $F = k \cdot v$, where k for a particular size of ball is 0.32 Ns/m. What would the final velocity of the ball be if it were dropped from a high altitude? The ball's mass is 0.20 kg.

If the student realizes that, after a phase of accelerated motion, the gravitational force affecting the ball ($F_g = mg$) will equal the force of air resistance ($F = kv$), then the equation $kv = mg$ can be set up and solved for v, substituting the appropriate values for k (0.32 Ns/m), m (0.20 kg), and g (9.81 m/s^2).

The student gets credit for this problem if the value 6.1 m/s appears on the answer sheet. But that value might be obtained without the student's having a full conception of bodies moving at a constant velocity. Even if it is required that the student show the intervening steps, $kv = mg$ might appear on the answer sheet because it has been memorized from the text or picked up while solving other similar problems. Even with a somewhat deeper knowledge of gravitational force, the student may still not fully understand that underlying the relation between gravitational force and air resistance in this kind of problem there is the still deeper concept that a body continues to move at constant velocity when the resultant of all forces acting upon it is zero. Many kinds of partial and incorrect knowledge may also go undetected in such tests.

The Swedish group prefers to use in-depth interviews starting with "naked" questions of the form: "A car is driven at a high constant speed straight forward on a motorway. What forces act on the car?" or "A puck has left an ice-hockey stick and glides straight forward on smooth ice. What happens?" In such cases it is often found that students who can answer correctly at a surface level harbor various kinds of partial or incorrect conceptions. Also, by using the same or similar questions at different points during a relevant course, learning as a shift in

Table 1

Categories of Students' Conceptions in a Mechanics Course

		What is Focused Upon				
		Velocity	Movement	Inherent Force	External Force	Movement Energy
How Explanation Is Given	Equilibrium not considered	A_2				E_2
	Equilibrium at constant velocity	A_1		B_2		
	Equilibrium at rest		B_1	C_2	D_2	F_2

Note: Subscript 1 = car question; subscript 2 = hockey-puck question.

qualitative category of understanding can also be demonstrated. It is clear however that different students display different kinds of shifts. Many of these would not be detectable in conventional tests.

In one study of university students in a mechanics course, for example, two distinct conceptions predominated in the interview protocols associated with the car question (see Johansson, Marton, and Svensson, forthcoming). With the hockey puck question, at least six qualitatively different conceptions were apparent. These conceptions differed in terms of what was focused upon in the explanation and also how the explanation was given, defining the outcome space shown in Table 1.

A body in the kind of constant motion represented in the car question was understood either as having a constant velocity, due to the equilibrium of forces (A_1), or as having movement, due to a "motive inequilibrium" of forces (B_1). These conceptions differ on what is focused upon (velocity or movement) and also on how the explanation is given (using equilibrium at constant velocity or at rest). A body in the kind of decelerated motion represented in the hockey puck question was understood using one of four possible foci and one of three forms of explanation, as shown in Table 1. The puck might be described as having a velocity which diminishes due to forces opposite to the direction of motion (A_2), an inherent force which diminishes due to totally greater forces opposite to the direction of motion (B_2), an inherent motive force which diminishes due to totally smaller forces opposite to the direction of motion (C_2), an external pushing force which diminishes due to totally smaller forces opposite to the direction of motion (D_2), a kinetic energy which diminishes due to forces opposite to the direction of motion (E_2), or a motive kinetic energy which diminishes due to totally smaller energies opposite to the direction of motion (F_2). Different sorts of shifts were observed among these categories as a function of the relation of the question to the course and how well the course addressed the relevant content. It should also be noted that the ordering of hockey-puck conceptions, for instance, does not necessarily reflect their proximity to the correct or "authorized" conception. It is also clear that outcome spaces can differ in complexity for different questions, and that combinations of categories across questions can yield even more detailed descriptions of student understanding and misunderstanding.

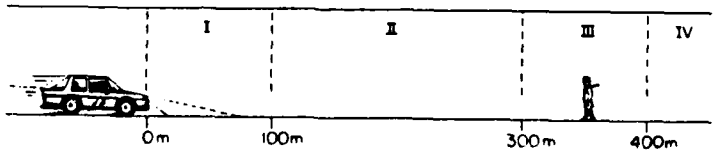
Now consider the question and response categories given in Table 2. The categories show the sorts of reasoning found among a large sample of

Table 2

Example of an Interview Question in Physics and Some Categories of Responding Student Conceptions

Question

On a clear, dark night, a car is parked on a straight, flat road. Th headlights are on and dipped. A pedestrian standing on the road sees the lights. The situation is illustrated in the figure below, which is divide four sections. In which of the sections is there light? Give reasons for answer.



Response Categories

A. The link between eyes and object is taken for granted. There is no pr can simply see.
B. A picture goes from the object to the eyes. When it reaches the eyes,
C. Beams come out from the eyes. When they hit the object, we see.
D. Beams go back and forth between the object and the eyes. The eyes sen beams which hit the object, return and tell the eyes about it.
E. The object reflects light. When it hits the eyes, we can see the obje

Table 3

Example of an Interview Question in Economics and Some Categories of Responding Student Conceptions

Question

Why does a bun cost one Swedish crown?

Response Categories

A. Irrelevant answers (e.g., "I like buns").
B. Price is determined by properties of commodities such as taste, shape, etc.
C. Price is determined by the value of commodities or the accumulated val their constituents.
D. Price is determined by the relationship between supply and demand for ties.

Swedish high school students (see Andersson and Kärrqvist, 1981; Marton, 1983). Although 38 percent of the seniors could give a correct verbal answer to the question "What is the key idea of optics?" when it had been made explicit in the text, very few stated that there is light in all sections (in response to the question in Table 2), and only 11 percent reasoned in a manner suggesting response category E. And it is interesting to note that those in category B seem to have a co to the "Eidola" of the at ancient Greece, while those i C display Euclid's concept o sight."

Table 3 shows one of the questions used by Dahlgren (study of an economics course year college students. Althou proportion of the students ga able answers to quantitative e questions on such topics, very

Table 4

Example of an Interview Question in Geography and Some Categories of Responding Student Conceptions

Question

Why is the side of a mountain that faces the coast usually wetter than the side facing inland?

Response Categories

A. Irrelevant answers (e.g., when we go to our cabin on the coast it is always wetter there than on the road crossing the mountains; I hate rain).
B. Sea breezes hit the coastal side of the mountain first.
C. Sea air is damp and foggy. It settles on the coast first. It rains there and then there is none left for the other side of the mountain.
D. The prevailing winds are from the sea. They pick up moisture from the sea. As they meet the mountain, they are forced up and get colder, because air higher above sea level is colder. This makes the moisture condense which forms rain on the side going up. When the winds cross the mountain they are dry.
E. If the prevailing winds are from the sea, they pick up water evaporated from the sea which is carried to the mountain slope where the damp air mass rises and cools. Cooling causes water vapor to condense and being heavier than air, droplets deposit as rain. Now the wind is drier, so it is carried further up the mountain where it compresses and so gets warmer, like a bicycle pump, so it is less saturated. The effect is like the chinooks on the eastern slopes of the Canadian Rockies in winter. Without the mountains there would probably be no difference between coast and inland. The energy exchanges depend on land features and the prevailing wind and temperature conditions.

answer direct interview questions on the concepts involved. After the course more students gave answers indicating category C conceptions than category D conceptions. Some even shifted from D before the course to C after it! It was noted that nursery school children often give category C answers to the same question.

Table 4 shows a question and response categories on an aspect of geography taken from Australian work by Biggs and Collis (1982) that is closely related to the Swedish work (see Marton, "Outcomes," forthcoming) As in the earlier examples a rough gradation of qualitatively different conceptions seems apparent. Biggs and Collis call these levels:

1. Prestructural--an irrelevant or otherwise inadequate attempt to learn a component, as in A;
2. Unistructural--one relevant component is acquired, as in B;
3. Multistructural--several relevant components are acquired, but additively and independently of each other, as in C;
4. Relational--the components become functionally or conceptually interdependent as in D;
5. Extended abstract--the integrated components become part of a more general case, as in E. Note also that the response in category E uses analogical reasoning as well as personal knowledge of a particular geographical area.

Whether these or similar levels of learning might be discernible more generally across science content areas is a question for continuing research. But an intriguing possibility, also suggested in some of Marton's writing (see "Towards a Psychology Beyond the Individual," forthcoming), is that the early history of science similarly displays such gradations in conceptualization and that transitions between levels may be as momentous for individual learners as they have been in the growth of science. Beyond pre-Aristotelian "primitive mentality," one can define an Aristotelian logic in which explanations are based on the inherent characteristics of sharply distinguished entities and then a Galilean mode of thinking, where explanations are based on relations between entities. Beyond this level, there is a post-Galilean form of conceptualizations in which entities are not only related to one

another but are defined by relation to one another in a system. Marton foresees a transition to this level for psychology through phenomenography, and draws parallels with other contemporary criticisms of cognitive science such as Winograd's (1980) call for a shift away from theories of internal processing relations toward theories of dialogues between man and machine.

Whatever comes of Marton's attempt to transform psychology through phenomenological argument, it is clear that the approach he and his coworkers have taken to the description of learning in science offers a rich means of diagnosing the various qualitative states of personal knowledge that may impede learner transitions from novice to expert. By focusing on intra-individual as well as inter-individual differences in these qualitative states and categories, and by avoiding automatic generalizations to all learners, contents, and contexts, the approach also produces a descriptive database about personal knowledge that should enrich research on human and artificial intelligence.

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1/16/84

BIOLOGICAL SCIENCES

BIOINTERACTIONS'84 CONFERENCE EXAMINES INTERACTION OF TISSUES AND MATERIALS

by Thomas C. Rozzell. Dr. Rozzell is the Liaison Scientist for Biological Sciences in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on reassignment until August 1985 from the Office of Naval Research, Arlington, VA, where he is Program Manager for Cellular Biosystems.

Oh, powerful bacillus,
With wonder how you fill us,
Every day!
While medical detectives,
With powerful objectives,
Watch your play.

"Ode to the Bacillus"
Wm. Tod Helmuth

The interactions that occur at the interface between a biomaterial and the tissue of the host in which it is placed is at once complex and little understood. Scientists, engineers, and clinicians engaged in the study of such phenomena are drawn from materials science, biochemistry, physiology, pathology, immunology, pharmacology, molecular biology, bacteriology, and toxicology. It is little wonder that a major task of a biomaterials workshop, held last year in Washington, was to define exactly what is meant by a "biomaterial."

The journal *Biomaterials*, published by Butterworth Scientific, sponsored a conference entitled "Biointeractions '84" at City University, London, from 4 through 6 January. This symposium, attended by about 100 people from all over the globe, seemed to be comfortable with what a biomaterial is, but wrestled considerably with the concept of biocompatibility--what it is, how to assess it

in a material before it is put into a human, and what the consequences are to recipients if the material is not biocompatible.

As James Anderson of Case Western Reserve pointed out in one of several invited presentations, it is no longer sufficient to describe the biocompatibility of a material in terms of the morphological appearance of the inflammatory reaction of the tissue surrounding the material, for the inflammatory response itself is a series of complex reactions involving various types of cells whose densities, activities, and functions are controlled by various endogenous mediators. Until recently (within the last few years), histological evaluation of tissue adjacent to implanted materials has been the most commonly used method of evaluating the compatibility of a material.

Anderson went on to point out that the macrophage is the major cell to be considered in the course of events that follow the introduction of a biomaterial into the body. The introduction of most materials into the body requires a surgical procedure or follows a wound. In either case, healing must be initiated.

The surface characteristics of the implanted biomaterials play a major role in determining macrophage activity. The ability of activated macrophages to secrete products capable of modulating cell-cell interactions and cell-mediator interactions suggests that both nonadhesive and adhesive events are important in the macrophage response to biomaterials. In fact, the mere presence of a biomaterial surface can enhance infection. This was demonstrated quite some time ago and reemphasized by Kathy Merritt of the University of California, Davis. Whereas it takes 10^6 organisms to cause an infection in normal skin, it only takes 10^2 organisms to cause an infection in the presence of a suture.

The phenomenon of adhesion--a complex, two-stage process--was discussed by H.W. Fowler of (University College of Swansea). He pointed out that adhesion theory is of little value now in predicting whether cells will, or will not, attach and [illegible] assessing the overall forces involved.

Most of the methods to measure cell adhesion are based on removal of attached layers of cells which depends on the cohesive strength of the cell/substrate complex rather than the primary adhesive energy governing the cell to the surface in the first place. Sensing that a knowledge of the latter may be important, Fowler set out to develop a technique to measure cell adhesion under dynamic conditions in terms of the maximum shear force against which adhesion stabilization can occur. For this purpose, he used a radial flow chamber in which defined flow conditions could be obtained by radial flow between parallel disks.

The problem of infection is receiving more attention with the increasing use of porous materials since the surface area is greater, permitting tissue ingrowth into the biomaterial. Merritt and several other investigators studying porous implants have shown that the rate of infection is increased if the organisms are encountered early but decreased once tissue has grown into the pores and formed a lining over the surface. Thus, it appears that before tissue ingrowth the organisms are capable of evading the defense mechanisms of the host. Once tissue ingrowth has occurred, host defense mechanisms at the site prevent infection. The clinical observation that many infections at the site of an implant are caused by low-virulence organisms has led to a number of studies of the ability of cells and bacteria to adhere to the surfaces of biomaterials. Merritt further pointed out that many organisms adhere to plastics, such as poly vinylchloride (PVC) and poly (methyl methacrylate) (PMMA) to a greater extent than to metals. It is thus evident from such studies that chemical makeup and surface texture affect infection rates and must be considered before new materials are approved for widespread use. It is no longer sufficient to show that a biomaterial is "inert," for we now know that changes can occur at the surface that are unrelated to the inherent composition of the material.

Metals released from implants due to wear and corrosion are known to be toxic to tissue. Most toxic reactions cause damage to the adjacent host tissue and thus provide a site for eventual colonization by bacteria. Sensitivity to metals has been associated with sensitivity reactions to implants in experimental animals; there is fairly good evidence in the guinea pig and rabbit that sensitivity reactions to implants alter the tissue response and result in inflammation and bone loss. There seems to be little question that these reactions occur. The real question is how frequently they occur. While about 13 percent of the normal population is sensitive to nickel, Merritt noted that she does not observe sensitivity to nickel in 13 percent of her patients who have stainless steel implants. It is thus clear that other factors play a role in this problem--such as quality and composition of the

alloy, location of the implant in terms of likelihood of wear and corrosion, and level of activity of the patient.

The problems associated with wear and corrosion and the cytotoxicity of a range of metals were addressed by several speakers at the symposium. Pourbaix of the Belgian Center for Corrosion Studies in Brussels, the acknowledged dean of electrochemistry of metallic corrosion, presented a very comprehensive and excruciatingly detailed overview of the salient features of the behavior of metal ions in a host of solutions and environments. From a more practical standpoint, R.A. Buchanan (University of Alabama, Birmingham) gave details of work that he and J.M. Williams (Oak Ridge National Laboratory) have done in modifying the surfaces of metals using ion implantation. By implanting nitrogen into the surface of the alloy Ti-6Al-4V until the nitrogen concentration reached 20 percent at a depth up to 1000 angstroms, they were able to reduce corrosion due to wear friction by a factor of at least 400 and to increase hardness of the alloy by approximately 50 percent. Buchanan pointed out that all corrosion affects wear and all wear affects corrosion, and in an articulating joint these two processes occur at the same time, often acting synergistically.

In what had to be the most international study reported at the symposium, L.C. Lucas (University of Alabama, Birmingham) reported on her investigation of the toxicity of low-gold alloys for dental applications. The research was carried out cooperatively with A. Hensten-Pettersen of Oslo, Norway, and L. Niemi of Turku, Finland. Using an epithelium cell line, they evaluated the biocompatibility of six alloys containing varying amounts of gold, silver, copper and zinc. She reported that the cell culture toxicity profiles indicated that the alloys that were relatively high in silver and copper were most toxic--with DNA synthesis alteration found at 2.5 and 10 ppm, respectively--while gold and zinc were significantly less toxic. They are planning to continue these studies to see whether synergistic influences are at work.

While many of the presentations focused, as much of the research does, on the host response at the site of the implanted biomaterial, Jonathan Black (University of Pennsylvania) put it all in proper perspective. His keynote paper on the systemic effects of biomaterials gave a vivid, slightly humorous, and all too true analogy between a scanning electron microscope view of an interface-tissue site and a diagram of the battle of Waterloo. He graphically pointed out that the view presented by the SEM picture, taken days to weeks after the reactions have occurred, tells the histopathologist no more about the dynamics of the interactions that took place than can be felt by a person who arrives at the scene of a great battle days later and simply sees the scattered bodies, bits and pieces. He went on to point out that the tendency of students of Waterloo is to concentrate on the battle itself, examining maps, diaries, artifacts, comparative technical studies of weapons and tactics, and so forth. This tendency to focus on the battle itself thus causes the scholar to miss the larger social, political, and economic setting that makes it possible to understand the conflict, its origins, and its consequences. In the same manner, he pointed out, studies of host responses tend to focus almost solely on the local responses to the implant. This can lead to erroneous conclusions in the same way that examination of battles outside their historic context does. Black urged the gathered audience to take a broader view of the variety of actual and possible systemic effects of carcinogenic, metabolic, immunological and bacteriological nature. With the early understanding that the body is composed of vast populations of nearly identical cells and constitutes a coordinated set of interacting physiological systems, the concentration on implant site phenomena is difficult to understand.

According to Black, there is a general lack of recognition of the presence of systemic effects in patient populations. Such effects may be totally unforeseen, and when they are found they are "away from" the implant.

Black divides systemic effects into four types: carcinogenic, metabolic, immunologic, and bacteriologic. While it could be argued that the latter two types could be combined, and that carcinogenic effects probably arise from failures of the immune systems, this is a reasonable scheme for examining systemic effects, and a few salient points can be made about each one.

Carcinogenic Effects. Studies of implanted biomaterials in animals have revealed considerable reason to suspect the possibility of chemical carcinogenesis. Metal ions, such as Ni^{2+}, Co^{2+}, and Cr^{6+}, as well as monomers such as vinyl chloride--all of which can be released by implants or blood contact devices--have been shown to be either primary carcinogens, co-carcinogens, or carcinogenesis promoters.

Chemical carcinogenesis secondary to implant use, if it exists, should probably be considered primarily a systemic effect. Since implants are most frequently placed in tissues that are not particularly sensitive to primary tumor genesis (bone, heart, etc.), implant site tumors in humans are largely unknown or unrecognized. Remote site tumors have been reported in association with implantation of clinical-type metal alloys in rats, and subsequent studies showed an apparent relationship between nickel release and tumor incidence. Also of concern should be the possible transport of particles to the lungs by macrophages. If these particles exceed the apparent lower size limit (0.22μ) for foreign body carcinogenesis, their accumulation should be a matter of concern. A recent study of high specific-surface-area titanium alloy implants in the baboon showed significant time-dependent aluminum and titanium accumulations in the lungs but not in other tissues. The study is suggestive of such a particle transport effect.

Metabolic Effects. The two principal classes of degradation products, metallic ions and monomers, are soluble to one degree or another and thus enter into metabolic processes. The breakdown into these two classes is a bit of an oversimplification. Actually, metallic release from implants probably results in production of only organometallic ions, while polymer degradation products may be larger than monomers.

Metals play a large part in metabolic processes. In fact, it is safe to say that there is hardly a single enzyme-catalyzed reaction in which either substrate, product, enzyme, or some combination within the triad is not influenced in a very direct and highly specific manner by the precise nature of inorganic ions which surround or modify it. At one time, metals were divided into three classes, based on their normal activities: the physiological metals (Na, K, and Ca), the essential metals (Co, Cu, Fe, etc.), and the toxic metals (Pb, Cd, Hg, etc.). It was recognized that there was a fourth class--the neutral metals, such as titanium--that had no apparent biological activity. This view is changing somewhat to a more pharmacological consideration of each metal, with a dose-response curve characterized by a low concentration regime of low or no effect, an intermediate concentration regime encompassing dose-related positive or beneficial effects, and a high dose regime of inhibitory or toxic effect. The study of trace elements now possible with some of the newer analytical techniques, such as neutron activation analysis and plasma excitation atomic absorption spectroscopy, will probably result in the discovery that most of the so-called neutral metals possess some level of biological activity. Of the principal metals present in most implant alloys, all but possibly titanium and some of the refractory metals (Nb, Ta) are now known to have biological effects.

The introduction of monomers into metabolic pathways is usually of little consequence as long as bizarre metal- or halide-bearing molecules are avoided in materials' fabrication, since polymers contain chemical bonds that are "familiar" to mammalian biological systems. However, it is possible that polymer degradation products that resemble, but are not identical to, metabolic intermediates might enter into substrate pools and function in an adverse, competitive manner.

Immunological Effects. There is less speculation about the immunological effects of implanted biomaterial products. It is well known that implants can invoke both B- and T-cell mediated immune responses. As several speakers pointed out, these arise in clinical populations with both metallic and polymeric biomaterials. Debate continues about the exact nature of the implant site effects; the research literature documents a range of remote site immune system responses, including urticaria (hives) and asthma, that are precipitated by biomaterials and that disappear upon removal of the challenge. Furthermore, it has been shown that metallic implants themselves can cause immune system sensitization; i.e., the reactions are not solely the result of challenging already-established hypersensitivities.

All immune effects must of necessity be classified as systemic effects, whether the antigen-antibody complexing occurs at the implant site or elsewhere. However, in spite of a large amount of clinical evidence of such effects, little attention has been paid to this area. Thus, little is known about occurrence rates, sensitivity thresholds, or severity of consequences, both acute and chronic.

Bacteriologic Effects. Just as trace elements play an important role in mammalian cell metabolism, they are known to be important in bacterial metabolism. Iron, for instance, is the metal whose concentration appears to be the most important in the enhancement and suppression of bacterial disease in

mammals. Chromium, which binds to transferrin in serum competitively with iron, can affect the synthesis of hemoglobin as released iron is moved to storage depots. It appears that corrosion products suppress chemotaxis, a vital step in the suppression of bacterial infection by host cells. Whether these effects are reflected in a greater systemic infectability of implant patients is unknown; this, according to Black, is yet another area devoid of clinical studies.

One of the most exciting applications of biomaterials is in the delivery of drugs (see next article). It has recently been realized that advances in biomaterials technology should make it possible to do a lot more than simply carry drugs into the stomach and slowly release them. The current dream of biomaterials researchers is to be able to direct a drug to a target organism and release it at a constant, predetermined rate. Another, more ambitious dream involves not only targeting the drug to a specific organ but starting and stopping the delivery of the drug on demand. This capability would have tremendous impact in a number of military and civilian applications. Two keynote papers and two contributed papers addressed facets of drug delivery. The tone was set by Jindrich Kopecek (Czechoslovak Academy of Sciences), who reported on his efforts to link active but toxic pharmacological agents to carriers that transport them selectively to the site of action.

Kopecek's idea is to couple an intracellularly active drug to a macromolecule, the effect of which is to automatically alter the distribution of the drug in the body. Pinocytosis and transfer into the lysosomal compartment is the major route by which carriers can deliver drugs intracellularly. To increase the specificity of this process, the carrier should contain moieties able to recognize the target site selectively. The bond between the drug and the carrier should be stable during the transport from the site of administration to the site of action. This implies that one should use bonds that are stable in the bloodstream and extracellular space, but that could be controllably released after penetration of the drug-carrier conjugate into the intracellular space, either by lysosomal enzymes, or due to the acidic milieu of lysosomes.

Several problems have to be solved before these new types of drugs reach clinical practice. The two most important ones are the biodegradability of carrier-drug conjugates and their immunogenicity. Both problems were discussed by Kopecek in his paper, with emphasis on synthetic polymers containing oligopeptide sequences.

Perhaps one of the most exciting new developments in the area of controlled drug delivery is the use of hydrogels. Hydrogels are polymers that will absorb a significant portion of water and swell without dissolution. They comprise both natural polymers such as cross-linked proteins, starches, or cellulose derivatives, and synthetic polymers and copolymers of hydroxy alkyl methacrylates, N-vinyl-pyrrolidone, acrylamide, acrylic and methacrylic acids, polyethylene glycols, and cross-linked poly(glutamic acid).

One of the leading investigators in this field is Prof. N.B. Graham of the University of Strathclyde. In another keynote paper, he discussed the physical properties (such as number average molecular weight, specific and changing diffusion coefficients) of crystalline/rubbery hydrogels based on poly(ethylene glycol). He showed how it is possible to control the rate of diffusion of the drugs through the water-swollen matrix and across the polymer boundary, and how to obtain a desired zero-order release rate as the hydrogel absorbs water. One way of controlling the release rate is to vary the thickness and shape of the hydrogel.

Over the past few decades many families of chemicals have been found to have a very marked physiological effect in minute quantities. For example, many steroids, peptides, and prostaglandins are active in man in daily doses of micrograms. The body protects itself against its own very active species, such as prostaglandin E_2(PGE_2), by rapidly destroying them, e.g., in one passage through the lungs. The biological half-life of PGE_2, as with most prostaglandins is thus very short. Pharmaceutical chemists have attempted to solve this problem by devising novel prostaglandins with a longer *in vivo* lifetime. Though many prostaglandins are now known, Graham feels a quite different approach could have been used. This would have been to stabilize prostaglandins and to deliver them in a continuous and controlled manner into the body. Currently, this treatment is only possible by intravenous therapy, which by its nature is very restricted. Several diseases are currently treated in this manner with prostaglandins.

The prospect for the use of prostaglandins in more conventional pharmaceutical formulations has been opened up by

the discovery that at least some of these unstable materials are stabilized at 4°C for a year and for at least 6 months at room temperature when incorporated into cross-linked polyurethane poly(ethylene oxide) hydrogels. Cross-linked starch hydrogels have also been shown to extend the shelf-life of PGE_2 to 1 year when they are incorporated in it.

There is considerable interest in using polymeric microspheres as a means of improving the perenteral administration of certain classes of drugs, especially those used in cancer chemotherapy. Attention has focused on fabricating such spheres from man-made lactide and lactide/glycolide copolymers. Another candidate material is poly(ß-hyrdoxybutyrate) (PHB), a polymer produced by bacteria. (I reported on this polymer in ONR, London, *Science Newsbrief* 1-1-83.) Drug-loaded microspheres have been made of this polymer, even though it is relatively crystalline. Recently, Imperial Chemical Industries of Billingham, England, found that bacteria can also produce copolymers of PHB and hydroxyvalerate, M.-C. Bissery and F. Puisieux (University of Paris) and S. Summerfield, T. Lenk, and C. Thies of (Washington University, Saint Louis, MO) presented their results of efforts to form drug-loaded microspheres from a series of such copolymers. The polymers they used contained from 9 to 33 percent hydroxyvalerate and ranged in molecular weight from 20,000 to 100,000. They were able to incorporate a low payload of about 7 to 8 percent of a chemotherapy agent in a copolymer containing 20 mole percent hydroxyvalerate. The drug could be released totally in about 24 hours or longer if desired, the time being controlled by the amount of hydroxyvalerate. I have examined this new copolymer, and its properties are indeed unique.

Several other new and interesting findings were reported at the symposium, one is detailed in the following article. The entire field of biomaterials gets more exciting each day as the frontiers of chemistry, physics, metallurgy, ceramics, biology, and medicine march forward.

1/23/84

PHOSPHOLIPID POLYMERS FORM BASIS FOR NEW BIOCOMPATIBLE MATERIAL

by Thomas C. Roxsell.

As pointed out in the previous article, the surface of a biomaterial is critical in determining its biocompatibility. If the surface of the material can be fashioned to resemble the surface or membrane of normal mammalian cells, the *in vivo* compatibility should be enhanced. It is now generally accepted that the cell membrane is a bilayer, fluid lipid matrix in which proteins and glycoproteins are "dissolved." There are three major types of lipids in cell membranes: phospholipids, cholesterol, and glycolipids. Each type is amphipathic, i.e., it has a hydrophilic end and a hydrophobic end. While there are upwards of 100 distinctly different lipids in mammalian cell membranes, the major phospholipid is phosphatidylcholine (lecithin). Lecithin-water systems have been extensively studied as models of biological membranes.

Over the past several years, an active group at the Department of Chemistry and Biochemistry at the Royal Free Hospital School of Medicine (RFHSM) in London has been developing biological membranes based on polymerizable phosphatidylcholines. The advantages of using phosphatidylcholines as biological membranes are as follows: (1) monomeric phosphatidylcholines have been well characterized in model systems and thereby provide a basis for comparison, (2) phosphatidylcholines represent the major phospholipid in human cell lines, (3) the rigid crystalline lattice of some polymeric phosphatidylcholines should increase the stability of membrane model systems, and (4) polymeric phosphatidylcholines should mimic the interfacial characteristics of nonreactive cell surfaces and hence form new, potentially hemocompatible materials.

The group working on these phospholipid polymers is headed by Prof. Dennis Chapman, who along with James A. Hayward has just completed a chapter for a book that summarizes their work over the past few years (see also *ESN* 37-6:204-205 [1983]). Much of the material for this article is drawn from a preprint of that chapter that the authors kindly provided and from a paper presented at the Bio-Interactions '84 Symposium reported in the preceding article.

Chapman and coworkers have synthesized phospholipid molecules containing diacetylenic groups in their acyl

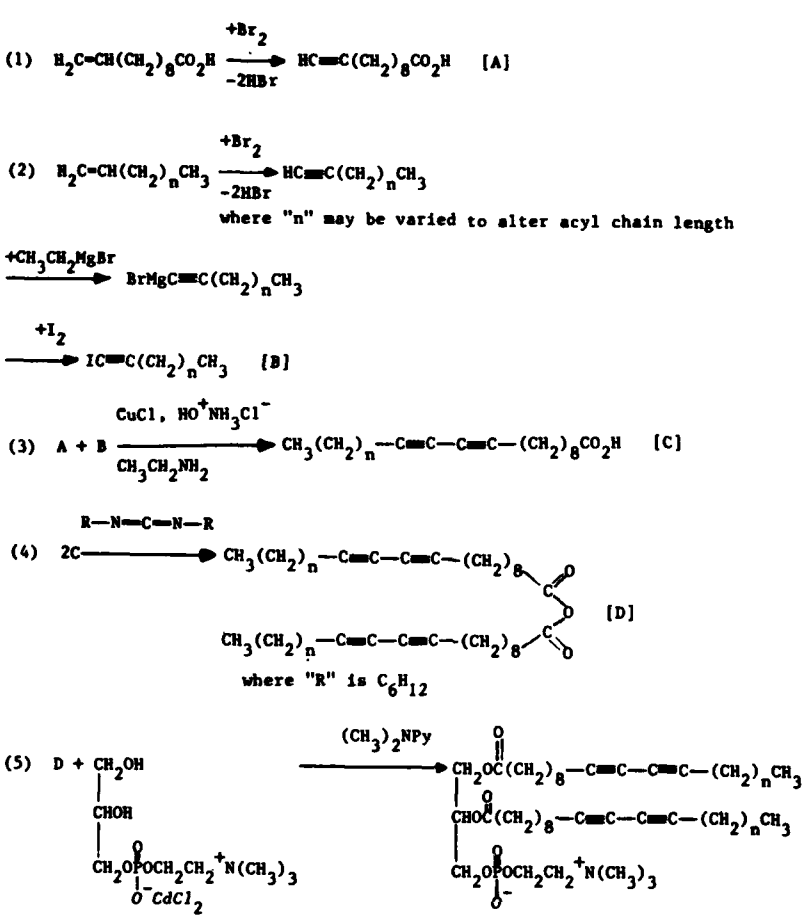

Figure 1. Synthesis of diacetylenic phosphatidylcholine; Py = pyridine (after Johnson et al., 1980).

(hydrophobic) chains, and these phospholipid molecules can then be made to polymerize by irradiating them with ultraviolet light. The schematic outline of the synthesis of diacetylenic phosphatidylcholine is shown in Figure 1 (Johnston et al., 1980).

They have prepared phosphatidylcholine molecules containing diacetylenic groups in both acyl chains (identical-chain polymer) and also lipids having a fully saturated hydrocarbon chain on the sn-1 position of the glycerophosphocholine moiety and a diacetylene-containing chain on the sn-2 position (mixed-chain polymer) (Johnston et al., 1983).

When they looked at the properties of the monomeric diacetylenic phospholipid, it was found that these properties resembled those of naturally occurring lipids (Pons et al., 1982a, 1982b, 1983). The relaxation times both for the head groups and for the resolved resonances in the acyl chains were very similiar in bilayers composed of diacetylenic or nonpolymerizable phospholipids. The monomers exhibited a mobility gradient along the acyl chain, although the motion in the region of the acetylenes was restricted. The motion is less restricted in this region of monoacetylenic lipids than that of diacetylenic lipids. Electron spin resonance was used to confirm the mobility gradient in diacetylenic phospholipids and demonstrate that polymerizable phosphatidylcholines display increased freedom of motion relative to saturated phosphatidylcholines (Johnston et al., 1983).

Polymerization of diacetylene proceeds fastest when the crystalline phase of the polymer most closely resembles that of the monomer. Polydiacetylenic phosphatidylcholines display a striking red color during polymerization. Raman and ^{13}C-NMR spectroscopy have been used to show that ultraviolet irradiation causes the two conjugated triple bonds of the monomer to be

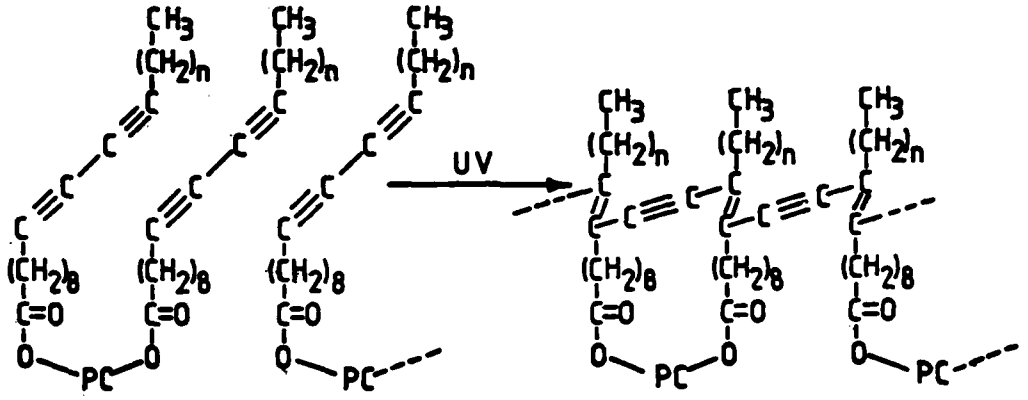

Figure 2. Formation of the polyconjugated phospholipid polymer from the diacetylenic monomer (PC = phosphatidylcholine).

rapidly replaced on the polymer by an alternating double-bonded and triple-bonded conjugated structure, as shown in Figure 2.

Polymerization of the phospholipids can be induced under several conditions: compressed in KBr pellets (i.e., in the solid state), dispersed in aqueous solutions, arranged as a monolayer at the interface between air and water, deposited as multilayers on suitable supports, or following biosynthetic incorporation of diacetylenic fatty acids into the membranes of living cells. The workers at RFHSM have also shown that monolayers of diacetylenic fatty acids still polymerize even when diluted with cholesterol or gramicidin (Johnston et al., 1980), although the degree of polymerization became limited when the monolayer contained more than one molecule of cholesterol per molecule of acid or more than one molecule of gramicidin per four molecules of acid. The capacity for polymerization of monolayers of diacetylenic phospholipid appears to be especially dependent upon chain length. Hupfer et al. (1981) found that monolayers of the C_{26} (n = 12) identical chain phosphatidylcholine could be polymerized in the condensed state, and that polymerization was evident by a change in surface area. In contrast, Chapman's group found that the shorter-chain homologues were not polymerizable in monolayers. Steric hindrance at or near the head group may prevent some diacetylenic phospholipids from polymerizing at an air-water interface, while the fatty acids readily polymerize under these conditions. Polymeric monolayers may, however, be prepared from solutions of the polymer in chloroform.

Because of their amphiphatic nature, phospholipids form a monomolecular film when spread at an air-water interface. Formation of an insoluble monolayer requires a hydrocarbon chain long enough to render the molecule insoluble, and a hydrophilic head group that interacts with the aqueous domain. Monolayers stimulate the conditions at the membrane-water interface, and their manipulation yields information about the intermolecular interactions of monolayer components. Looking again at the structure of the monomeric phosphatidylcholine in Figure 1, note that the position of the diacetylenic group can be varied along the acyl chain. The properties of the monomer and the influence of polymerization depend upon the position of the polymerizable group and the length of the acyl chains.

When dispersed in water and heated above the temperature of the phase transition, phospholipids spontaneously swell and form sealed vesicles, liposomes. The utility of liposomes is limited by their leakage rates and tendency to aggregate, fuse, or precipitate. Nonetheless, they are popular as models for studying biological membranes, and they have received much attention as pharmacological "capsules." Attempts to increase the stability of liposomes have included the incorporation of cholesterol into the bilayers and the modification of surface charge. The formation of multilamellar spherical vesicles by diacetylenic phospholipid polymerize upon exposure to ultraviolet radiation. The vesicles appear to retain their shape after irradiation. Some diacetylenic liposomes have been found to be permeable to glycerol before polymerization. This may be due to the increased freedom of motion conferred by the acetylenic moieties near the bilayer center. Permeability was temperature-dependent and increased in the region of the phase transition. Polymerization caused a marked reduction in

permeability and greatly reduced the tendency to precipitate. Moreover, the liposomes' spherical morphology appeared unaltered in high salt or solutions of 50 percent ethanol. The size of diacetylenic liposome vesicles influences their capacity to polymerize. Very small, unilamellar liposomes do not polymerize at any temperature. The enhanced stability of polymeric lipsomes gives them great promise for applications as carriers of drugs *in vivo*. The reconstitution of proteins within polymerizable lipid bilayers and the capacity for retention of conformation or stereochemical specificity may prove useful in targeting drugs to a particular site and in the study of cell-cell and cell-surface interactions.

Once polymerized, diacetylenic lipids exhibit thermochroic behavior, changing from yellow to red as the temperature is raised. Identical-chain polymers of phosphatidylcholine exhibit reversible thermochroism, and spectral changes occur at lower temperatures than for mixed-chain polymers. The lower temperatures required for thermochroic changes of identical-chain polymers are consistent with their lower mean molecular weights.

The RFHSM group has also looked at the hemocompatibility of polymeric liposomes. Others have shown that photopolymerized liposomes do not interfere with platelet aggregation *in vitro*. In the presence of increasing amounts of liposomes prepared from a monosubstituted, diacetylene phosphatidylcholine the rate of clot formation was not altered. Likewise, polymerization of these vesicles did not alter their nonthrombogenic nature. Chapman's group feels that this gives weight to the belief that materials that mimic the surface of red blood cells should be hemocompatible, and suggests that the polymeric phosphatidylcholines may find extensive applications *in vivo*. They are currently conducting isothermic studies of the effects of membrane fluidity on hemostasis using polymerizable phosphatidylserines in coagulation systems.

The successful polymerization of diacetylenic lipids in mixed systems led to attempts to form similar polymers biosynthetically, i.e., polymerization *in situ* following incorporation of the monomeric lipid into the membranes of living cells. The biosynthetic incorporation of diacetylenic lipids involved both the phospholipid and glycolipid fractions, with no apparent preferential incorporation into any particular lipid class. Diacetylenic polymerization in this manner permits the study of immobilized membrane proteins, and may be useful with extrinsic membrane enzymes or with "structural" membrane proteins. The ability to gather membrane proteins into stable, monomeric domains may result in two-dimensional, crystalline structures that are useful in studying protein structure. In fact, an assortment of polymerizable, biocompatible membrane lipids may be obtained from cells grown on diacetylenic substrates, and this biosynthetic route may be simpler than the chemical syntheses of some complex lipids. Polymerizable glycolipids, present in large amounts in the membranes of these cells, may be useful in the study of carbohydrate involvement in cell-cell interactions.

While monolayer films are interesting, real utility comes in the use of multilayered configurations. Blodgett and Langmuir (1937) first demonstrated that a multilayered coating of lipid could be deposited onto a solid support by successfully dipping the support through a monolayer. Generally, such multilayered films are quite unstable. Diacetylenic phospholipids provide two significant advantages for the use of mulitlayered films: (1) polymerization of the diacetylene group gives rise to a perfectly regular polymer with a stable, crystalline lattice (polymerization inhibits the rearrangement and decay that occurs with multilayers of nonpolymerizable lipids), and (2) the ability to coat an artificial surface with a stable polymeric phospholipid should make the surface biocompatible, especially when the polymer is engineered to mimic the surface of host cells. The differences that have been shown between monolayers, bilayers, and multilayers of phospholipids in their capacity for polymerization suggest that the polymeric lattice is most closely approximated when the lipids are arranged to permit maximum interaction between the acyl (hydrophobic) chains.

The RFHSM group has developed procedures for preparing Blodgett-Langmuir type multilayers of diacetylenic phospholipids (Albrecht et al., 1982).. Multilayers of diacetylenic fatty acids, up to 12 layers thick, consistently presented a hydrophobic surface that readily polymerized above or below the monolayer subphase. In order to be useful as biocompatible surfaces, however, it is important that the surface of the device be polar. Phospholipid multilayers, up to 43 layers thick, presented strongly hydrophobic surfaces if they were polymerized after withdrawal from the subphase. The polar surface could be stabilized, however, by irradiating the multilayer under water.

Several substances--such as glass, quartz, teflon, and mica--have been coated with ordered layers of diacetylenic phosphatidylcholines in which the phosphocholine moiety formed the outer coated surface. After polymerization, the layers were quite stable in aggressive media and could be handled without damage if done carefully. The ability to modify the surface of existing materials by deposition of polymeric multilayers will certainly have important biomedical applications. The mechanical and topological properties of the material can be retained while the interfacial properties are changed to mimic the surfaces of the host cells.

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1/23/84

OFFSHORE DIVING CONTRACTORS CONFERENCE

by A.R. Manalaysay. CDR Manalaysay is Exchange Officer for Underwater Medicine at the Institute of Naval Medicine, Alverstoke, UK.

The Association of Offshore Diving Contractors (AODC) held a conference in Aberdeen, Scotland, on 2 and 3 November 1983. The theme of the conference was "The Problems Facing the Industry Now." The AODC's members, representing the UK and the Scandinavian countries, perform most of the diving services for the North Sea oil interests.

Two categories of problems were discussed during the conference: engineering/hardware and medical/safety. The AODC members are easily able to address the engineering/hardware problems because that is their main business. Advice on the medical/safety aspects, however, comes primarily from the Diving Medical Advisory Committee (DMAC). The DMAC's members have varied backgrounds and represent either the scientific or operational branches of the diving trade; they come from government, the military, the oil industry, and academic institutions.

The engineering/hardware sessions included discussions of the training of pilots for one-man submersibles, the training of underwater inspectors, the practical constraints when using electricity underwater, and systems for emergency life support and recovery of submersibles.

The DMAC released its latest "Guidance on Assessing Fitness to Return to Diving" during the conference. Other medical/safety-related topics included:

1. Recommendations about a minimum level of oxygen in helium supplies stored in offshore facilities
2. Recommendations about the choice of a therapeutic compression table in relation to the causative dive
3. Guidance notes on color coding and marking diving gas cylinders and banks
4. Revised recommendations about the number of paramedically trained divers on a diving team
5. Safety of diving operations which use surface decompression procedures
6. Thermal problems in diving--particularly emergency procedures when power supplies to a diving bell are interrupted.

A quick look at these topics shows that many of the problems discussed are

in fact multifactorial. The mixture of engineering and medical expertise of the participants made for valuable information exchange. The proceedings of the conference may be obtained from Spearhead Exhibitions, Ltd., Rowe House, 55/59 Fife Road, Kingston-Upon-Thames, Surrey KT1 1TA, UK.

1/18/84

COMPUTER SCIENCES

COMPUTER SCIENCE AT IBM GERMANY'S SCIENTIFIC CENTER AT HEIDELBERG

by J.F. Blackburn. Dr. Blackburn is the Liaison Scientist for Computer Science in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until September 1984 from the National Academy of Sciences, where he is Executive Director, Computer Science Board.

For the past decade IBM's Heidelberg Scientific Center has been developing new user-friendly interfaces to data and application programs. The objectives are to increase the productivity of application programmers and to enable specialists with little knowledge of data processing to develop programs and solve problems at interactive terminals without the help of professional programmers.

Recently this work has been extended to end-user interfaces for small and distributed systems, to systematic research on human factors of application software, to building competence in the methodology of information systems development, and to research in selected areas of scientific and engineering computing. Specifically, the following projects are under way or have been recently completed: user specialty languages (USL), integrated data analysis and management systems (IDAMS), advanced information management, very large systems, and distributed academic and scientific computing. Each of these projects was described to me by Dr. Albrecht Blaser, director of the Heidelberg Center.

User Specialty Languages

The USL project started in 1974. It was designed to determine the feasibility of using a subset of natural language (German, English, Spanish) as a query language interface to a relational database and data communication system for storage, retrieval, and analysis of data by nonspecialists in data processing. The objectives of the project were:

1. To develop the grammar rules and interpretation routines for that part of the natural language needed for data handling.
2. To use a general language definition facility to implement the selected language.
3. To develop a natural language question-answer prototype providing an application-independent subset of the natural language as a basis for application implementation.
4. To provide a technical environment for the evaluation of its usability by nonprogrammers.
5. To investigate required user guidance and learning, handling of user errors, and necessary extension facilities.
6. To experiment with different applications and to draw conclusions for other languages.
7. To compare the human factors of a restricted, natural-language database interface with those of formal, set-oriented query languages.

In the system a language-definition component processes definitions of words and grammar rules defining syntactically a query or command language. This component also incorporates processing routines for integration with grammar rules.

The prototype of the language definition component contains: (1) one of three grammars describing subsets of German, English, and Spanish, and (2) interpretation routines translating expressions from these subsets into expressions in the database language known as SQL (structured-query language). These definitions and interpretation routines constitute the application-independent core of the USL prototype. The vocabulary required to access application data is added to the language definition by the user.

Documentation of the German, English, and Spanish grammars has been completed. The vocabularies contain 400 to 500 words each. Adaptation to a particular application can be done in a few man-weeks. The implementation of a (Western) native language subset will require about one man-year.

The Integrated Data Analysis and Management System

This project was also started in 1974 and is now complete. Its purpose

was to explore the feasibility of using a comprehensive problem-solving and decision-support environment in one system to support planners, engineers, and scientists with little training in data processing. The support system includes: an extended relational-database management system to support data structures such as vectors, matrices, sampled functions, and measured or observed data; function libraries for predefined general-purpose or application-specific programs implemented in various programming languages; support for graphic presentation and manipulation of data and for report writing; an inventory component managing formal and descriptive information about the system and its data and programs; user guidance for inexperienced users; a high-level query language for data retrieval and analysis; and a programming language (APL) as interactive host language for data analysis.

Users of IDAMS must be knowledgeable about their application but do not have to be specialists in data processing. Users view their problem data and programs as collections of interrelated tables. Typically users set up a "query" (a specific data analysis or manipulation request) using the system's guidance to identify the tables and programs required to perform the processing. Then the data analysis interface (the high-level query language) is set up to define and execute the query, which does the processing. To support the selection, identification, and usage of objects, the information about them must have been inserted into the information network. This is normally done by application specialists. Once the user is fully informed about the objects to work with, they can do data manipulation, data presentation, or data definition and collection.

The following are some of the applications of IDAMS:

1. Investment decision and analysis support. This consists of a database on daily stock quotations of German stocks traded on the Frankfurt Stock Exchange from 1971 through 1976.

2. Operating system tuning. This deals with the implementation of a database for the administration and evaluation of system-measurement data in the Heidelberg computer installation and the development of queries for the display and analysis of this data.

3. Interactive database of performance data. A database and a set of standard queries allow characteristic quantities for selected computer installations to be displayed. An example is the distribution of transactions over the number of database accesses per transaction displayed as a bar graph.

4. Analysis of traffic accident data. This deals with the administration and analysis of data collected from traffic accidents in Berlin and Hannover.

Advanced Information Management

This project, started in 1978, deals with the architecture of an integrated system combining database management and information retrieval. The relevant problems were identified, including the necessary data models for conceptual and internal use, mappings between them, the data manipulation language, the indexing techniques for efficient data access, and an appropriate transaction management. Some of the solutions to these problems are highly significant, including reference-string and interval indexing techniques and the extended relational data model with the relevant algebra and data-manipulation language. The extended relational model allows both simple and complex objects as attribute values. The objects may be sets, lists, or tuples of simple or complex objects. (Tuples are collections of related elements.)

The model is suitable for text and data management, including requirements for engineering applications. The prototype supports list- and set-oriented predicates.

Different techniques for the management of concurrent and long transactions are being evaluated. A pharmaceutical database and office systems are sample applications that are being studied.

Very Large Systems

The time needed to access data in secondary storage is greater than for that in main memory; the gap continues to increase. Thus the systems of the future will require increased concurrency of operations to satisfy the growing demands of database/data communication and interactive end-user applications. This raises questions such as the following: how should systems of the future be structured; how well do present architectures of hardware and programming systems support future needs; how should applications and subsystems be structured to meet reliability, availability, predictablility, and serviceability requirements in heavily used systems; how should the end-user workload be isolated from operational applications; and how can software support hardware make better use of very large scale integration?

The approach at Heidelberg is to analyze the various phenomena in current systems under transaction-driven workloads and to extrapolate this experience to expected future environments. Also, an architecture will be developed using the principle of logically dividing the total system activity into subdivisions with strong interaction between parts of a division. Controlled and moderate interaction between divisions will also exist. This implies subsystem isolation, protection, and predictability.

Distributed Academic and Scientific Computing

This project is being undertaken as a joint effort between Karlsruhe University and the IBM Heidelberg Scientific Center. The objectives are: (1) to design and implement a prototype of a distributed academic and scientific computing system which supports the hardware and software required by students, faculty, and research staff in a university or research organization, and (2) to test it in actual use.

The hardware in the academic environment is a heterogeneous collection of computers which are nodes in a network. Each node is controlled by an operating system which has to be extended to provide functions for communication between the nodes.

The following requirements need to be met:

1. End users should have access to all levels of computing.
2. Programs should have access to data independent of the data location in the system.
3. Any node should be able to serve a selected group of users independently of where the service is implemented. Service should not be affected by the operational status of nodes which are not involved in the service.
4. It should be possible to add or delete nodes without updating central catalogues.
5. Data security and reliability must be supported. Monopolization of resources by end users should be prevented.

The equipment for the prototype university computing network will include the following components:

1. At least four mainframe computers, including one non-IBM computer and several intelligent workstations and personal computers with suitable communication interconnection.
2. One of the following systems for each computer: memory/system package (VM/S conversational management syste both IBM systems; Unix, deve Bell Telephone Laboratories; ar Digital Equipment system.
3. Extensions of operatin for support of network function
4. Compilers, subsystem device support software as need applications during evaluation.

The extent to which the satisfies the requirements for and scientific computing suppor evaluated in a realistic u environment. Applications prototype will be selected following university dep computer science, mechanical ing, electrical engineering, business sciences, and civil ing.

Applications will include courses with students as well cation of the system in adva search projects.

1/19/84

COMPUTER SCIENCE AT KARLSRUHE U

by J.F. Blackburn.

Karlsruhe University is on leading German universities in research. The four institutes faculty of computer science broad spectrum of research ran custom design of very larg integration to automatic theor ing.

Institute I deals with a intelligence, automatic theorem program verification, PROLOG, algorithms, computer algebra, s logic, parallelism, cryp man-machine communication, systems, graphic algorithms, a theory.

Institute II covers progra tures, compiler generators, piler, personal computers, analysis, database systems, s tion techniques, data securi software design methodology.

Institute III is concer distributed processing, comm systems, telecommunication, image processing, pattern rec

automation for public transportation, microcomputer systems, operating systems, security in operating systems, performance analysis and modeling of computer systems, local nets, and open nets.

Institute IV deals with microcomputers, custom-design very large scale integration, testing and failure analysis of digital circuits, and specification and design of digital systems.

The computing facilities available are:

1. A central computing center with a Siemans 7.760 with 120 terminals and 10 printers; a PDP 11/45; a Siemans 7.531; and two VAX 750's.

2. A distributed processing laboratory with the following: Siemans 320, 330, and R30; PDP 11/20, 11/34, 11/45, 11/40; and a VAX 750. ETHERNET is being installed. Several examples of research work in each of the institutes are discussed in the following paragraphs.

Theorem Proving

A theorem-proving system--under development since 1977 at Karlsruhe--is called the Markgraf Karl Refutation Procedure. The researchers are trying to build a theorem prover and augment it by appropriate heuristics and domain-specific knowledge so the following objectives are met: (1) it will display an active and directed behavior in striving for a proof, rather than a passive combinatorial search through very large search spaces; (2) it will not generate a search space of many thousands of irrevelant clauses, but will find a proof with comparatively few redundant derivation steps; and (3) it will offer an unprecedented leap in performance over previous theorem provers expressed in terms of the difficulty of the theorems it can prove.

About 25 man-years have been invested in this research, and 2 million bytes of LISP code have been written; the results indicate that objectives 1 and 2 have been achieved. Objective 3 has not been met; the system performs better than most other automatic theorem-proving systems, but on certain classes of examples--such as induction and equality--the comparison is unfavorable. However, the researchers believe this will improve with further development.

Analysis of Version and Configuration Control in Software Engineering

An important issue in software engineering is the management of the various versions of products and product components, and of various configurations into which the versions are assembled. Configurations are members of the product group that differ to some extent in their software components--where components are considered black boxes with only their interfaces accessible. Versions are members that are identically composed, but some of the components differ in their implementation with regard to performance, storage requirements, add-on features, and host machines. The situation becomes especially complex if the environment is supposed to support the entire system life cycle. The research at Karlsruhe demonstrates that the entity relationship model is ideally suited to identifying the various entities to be managed and the relationships among them that are to be observed. An entity-relationship model is developed through first introducing a software-engineering-environment model that takes the entire life cycle into account and that forms the basis for the entity-relationship analysis. An entity-relationship schema is then developed based on the entity-relationship model published by an International Standards Organization study group (Van Griethuysen, "Concepts"), together with a more refined and modified terminology. Some constraints are then included in the implementation of a database.

Database Systems for Computer-Aided Design Applications

A central database is an important factor in the integration of the phases of computer-aided design (CAD). Commercially available database systems are tailored for administrative application; thus they do not meet fully the requirements of CAD. Research at Karlsruhe began with an analysis of the main functions of a database system and then determined how they must be specialized for CAD applications. Methods were devised for developing the database structure in a system-independent way, for translating it into a database schema for available database systems, and for manipulating the databases. Several novel approaches to database design that hold considerable promise for CAD application are under development.

Concepts of Time in Modeling Information Preserving Databases

Many modern database applications must preserve a record of the past over and above the current states of application environment. For these applications the concept of time is of central importance. Databases that model these applications cannot be based on the

concept of state alone, but must replace it by the concept of history as a function from some temporal domain to some value set. These are called information-preserving databases. At Karlsruhe the consequences of the history concept were explored from a database design viewpoint. The entity-relationship model, discussed above, was extended to include histories, and the researchers introduced for the model a framework for inferring states of the past that have not explicitly been stored in the database. The framework is based on the notion of uncertainty and uses procedural means and ground rules for limiting uncertainty to a few well-defined situations. Update semantics are slightly more complex than in traditional databases.

For example, a banking application typically must preserve a record of the past. The basic entity is the individual account. Transactions that cause changes to an account are also modeled as entities. Because interest is credited to accounts, a third entity type, interest rate schedule, is added. Two relationship types relate an account to the rate schedule applying to it and to the transactions affecting it. Changes to the account have to do with the transactions (deposits or withdrawals) and with the interest accruing to the account, which is credited quarterly.

Prototyping Interactive Application Systems

Of critical importance to the success of any engineering or construction project is the prior identification, specification, and validation of the requirements to be satisfied. Specification requires precision, which leads to the mathematical models. Such models may not exist in practice, or they may not be sufficiently comprehensive. It has become practice in engineering to use prototypes that exhibit a substantial part of the functional properties of the final product. Used as a "live" communications vehicle, software prototypes are more understandable to the potential user than a written description. In this project Karlsruhe researchers are developing prototypes of interactive application systems (IAS)--that is, software systems that interactively solve clerical, managerial, and expert problems within business and technical environments. Because one needs to change scenarios when experimenting, prototypes must be quickly modifiable and again available for further investigation.

A prototype and the information gained from it are integral parts of the results obtained for the intended software product during the early phases of its life cycle. Parts of a prototype may be used to derive the functional specifications for the corresponding component of the final system. Some prototype software may even become part of the final system. Prototyping that involves only the early phases of the life cycle corresponds to what is called horizontal prototyping. It leads to an initial product that syntactically offers most functions of the final system but does not perform these functions in all detail. Involvement in all phases is related to vertical prototyping, which produces a limited but completely realized sample of the final system's behavior and may be augmented later.

For IAS prototyping both horizontal and vertical prototyping are used. The Karlsruhe researchers say, "We emphasize vertical prototyping, but then may augment it horizontally." The functions offered are dedicated to each end user's particular needs and responsibility. Tailoring of IAS will result in a huge number of individual function sets and interfaces, each one dedicated to a relatively small clientele; the services will be available at low cost.

Database Support for Software Development

Database management systems (DBMSs)--as compared with pure file management systems--have a number of attractive characteristics that suggest their use in software development environments for maintaining all the data produced during the software life cycle of a software product. Software development environments have rarely turned to DBMS support, in part because commercially available DBMSs have proven unsuitable, and in part because the DBMS requirements of software development environments are not well enough known to suggest alternative DBMS designs. A study is under way at Karlsruhe to overcome the second factor. Based on the requirements analysis for an ADA software development environment, a DBMS architecture and interface are proposed that draw on the American National Standards Institute three-level architecture (see "ANSI," 1975), which admits different data models for the various views. Finally, an implementation has been achieved that combines a commercial DBMS with conventional file management.

Practical Experience With Vertical Migration

The performance of microprogrammable computer-system architectures can be improved considerably by microcoding frequently executed and central processing unit-intensive software functions. At Karlsruhe, improvements in qualitative performance have been obtained by practical application of vertical migration techniques in a hierarchically layered software/firmware/hardware system Burroughs B1726. Various representative software primitives which make heavy use of the central processor when running have been microcoded and put into firmware. They include operating system and application software. Quantitative analyses demonstrate the range of performance enhancements which can be expected by the application of this technique (Grossman, 1984).

Differential Reflectance Functions and Their Use for Surface Identification

A rigorous vision model should incorporate a detailed understanding of the image-forming process. At Karlsruhe the radiometrical description of this process is formulated in a satisfactory way by differential (bidirectional) reflectance functions. The profitable engagement of these reflectance functions for the identification of surface properties (materials, defects) is a part of the first representational level of early vision. The Karlsruhe researchers use a linear polarized laser beam (nonsensitive to other natural light sources) in combination with a goniometer to measure the differential reflectance properties of typical industrial surface patches. The value of the reflected irradiance, the shape of the reflectance functions, and the depolarization effects of material defects are employed to identify surfaces or surface defects (Levi, 1983).

The preceding examples give a partial summary of some of the extensive work under way at Karlsruhe in the broad field of computer science. Clearly some of the work is in the forefront of research activity in computer software.

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1/24/84

DATABASE SYSTEMS AND SOFTWARE ENGINEERING AT STUTTGART UNIVERSITY

by J.F. Blackburn.

At Stuttgart University, computer science research is oriented toward software engineering and distributed database systems. The main research areas are design of database systems, software engineering, distributed database systems, and applications and specifications.

Design of Database Systems

The research group has introduced formal, abstract models for describing modern dialogue concepts offered by high-level user interfaces. The dialogue concepts are menus, forms, and windows (logical screens). Using these abstract models, one can achieve a formal definition of system states and state transformations which represent the basis for describing dialogue interfaces. Thus a formal definition of the semantics of user activities can be given. The specification method used at

Stuttgart is called the Vienna Development Method (see Bjorner, 1982).

Software Engineering

Graph structures are used as tools for selecting a suitable problem-solving method and for defining complex problem-solving methods in a descriptive way. These tools are based on an application model using different types of graph structures for: (1) representing the functional structure of an application by decomposing problems into appropriate sub-problem structures, and (2) describing the available problem-solving methods and the various relationships among them. A dialogue interface offers a way to gather information about the structure of a problem and about the methods available for solving a specific problem. Also, a definition mode is provided which can be used to combine existing problem-solving methods into more complex ones. Mechanisms have been developed which give users of decision support systems a descriptive specification of complex problem-solving methods. The decision support system is built on a relational database system. All problem-solving methods are realized as transactions executed by the underlying database system.

Distributed Database Systems

Work has been done on communications requirements of distributed database systems, protocols for checking the availability of remote sites, and replicated data and stable storage in distributed database systems. Among the projects which will be discussed later are communication in distributed database systems, a protocol for checking the availability of remote sites, and replicated data and stable storage systems.

Applications and Specifications

Researchers are developing methods of combining a database system with a library of application programs. The main idea is to use a sophisticated dialogue interface to handle the library and the database. There are three dialogue functions: (1) a modeling technique can represent the functional structure of an application making use of graph structures, (2) existing application programs can be combined into a more complex one, and (3) input data can be specified for each application.

Specific Projects

Several projects will now be described in more detail.

A Formal Approach to Semantics. The following aspects of the use of formal specification techniques for describing various aspects of database systems have been investigated:

1. Well-known traditional data models in which formal definitions of the data structures and operators of data models are found. The relational data model has been formally defined by Brodie and Schmidt (1982), and a formal definition of the hierarchical model has been given by Bjorner and Lovengreen (1982). These descriptions are used for comparing the different features of the various data models and for providing a standard actual system on which implementations should be based.

2. Database languages. Through the use of formal techniques, a formal definition of the semantics of database languages was achieved (see Gangopadhyay et al., 1982). Thus the definition of database languages came up to a level which can be compared to the definition of programming languages, where formal techniques have been in use for many years.

3. Protocols for transaction handling in distributed database systems. Formal techniques were used to specify complex protocols in order to be able to verify important features of the protocols.

At Stuttgart, concepts were introduced for formally specifying high-level user interfaces based on a window technique integrating a command language with forms and menus. The researchers assume that a menu and form-oriented interface will be built on top of two dictionaries: the menu dictionary, containing all available menus, and the form dictionary, describing all available forms. The menu dictionary is modeled by using a Vienna Development Method map, which is a finite function mapping a unique menu identifier to the corresponding menu. A menu can be selected by applying the map "menu dictionary" to a given menu identifier. Using the map concept guarantees implicitly the uniqueness of the menu identifier. For modeling a single menu they use a map associating menu-option identifiers (positive natural numbers) and menu options represented by strings. The window technique is also used to support the display of several logical screens (windows) on one physical screen (Studer, 1983).

In summary, the Vienna Development Method was used to formalize the functional specifications of high-level user

interfaces. By introducing formal models for menus, forms, and windows, the researchers were able to formalize the descriptions of states and state transformations for user interfaces based on these dialogue concepts, thus achieving a totally formal specification of the semantics of the user actions. The specifications of high-level user interfaces provided by this approach are much more precise than the specifications from a more conventional approach.

Using the Vienna Development Method. The Vienna Development Method is used to give a formal functional specification of a software system. An example is the Application Development and Support System (ADS), which is built on top of the distributed database system POREL. Using the semantics of the Vienna Development Method, one can formally define: (1) the semantic domain, i.e., the application model which is the basis for the dialogue support provided by ADS and part of the system state; (2) the syntactic domain, i.e., the user command language; and (3) the meaning functions defining the semantics of the user functions offered by ADS.

The schema for development used at Stuttgart is made up of: (1) analysis--analyzing the problem to be solved by the system, (2) specification--functional description of the system to be built, and (3) design--description of the system structure (subsystems, modules, processes, and data structures) required for realizing the functions defined in the system specification. Researchers at Stuttgart have used the Vienna Development Method, which adopted the denotational semantics approach to development.

This approach, which uses functions to denote the meaning of programming languages, can be characterized as follows. A syntactic domain describing the syntactic objects and a semantic domain containing object classes (domains) and meaning functions can be distinguished. By defining an interpretation function, each element of the syntactic domain is mapped to such a meaning function defining formally its semantics. In other words, the meaning of a syntactic object is defined by a function having object classes of the semantic domain as its domain and range. The Vienna Development Method offers the following standard data types: (1) set--a set of objects in the usual mathematical sense; tuple--a finite list of elements which are all taken from the same domain; (3) tree--combination of arbitrary objects into tree structures, which provide implicitly defined selectors for accessing the different tree components; (4) function--a normal mathematical function; (5) map--a function with finite domains.

Stuttgart's researchers have shown that the Vienna Development Method can be used to formalize the functional specifications of an interactive application system. They achieve a precise description of the semantics of the required user functions.

Graph Grammars. Stuttgart researchers have introduced graphics to visualize the structure of algebraic specifications. Such graphics support the stepwise formalization of the program components used, data types, and functions. However, graphics entail considerable administrative work. It is therefore suggested that a graph grammar be used to generate the graphs occurring at any development stage of a software system. The development activity requires a mechanical transformation of the graph grammar representing the actual development stage. The use of graph grammars allows the system developer to concentrate on intellectual work during the development process (Pletat, 1982).

Communication in Distributed Database Systems. Using a simple transaction model as an example, Stuttgart researchers argue that the basic service needed is a connectionless data transmission, and that services for multicasting and for the surveillance of remote sites are necessary. It is demonstrated in the project that higher level services for transaction-oriented message exchange and commit processing might be useful in order to achieve a more efficient implementation of distributed database systems and other distributed application systems (Walter, 1983).

A Robust and Efficient Protocol for Checking the Availability of Remote Sites. A remote site is available if it has not crashed and if the communication facilities are able to transmit messages to and from this site. The protocol developed at Stuttgart is robust against any number of site crashes and communication breakdowns, including network partitioning. It is proven that the protocol is minimal in the given context. Application to the recovery of multi-site transactions is an important capability (Walter, 1982).

Replicated Data and Stable Storage. Two types of redundancy are used in distributed database systems. Data are stored redundantly on multiple sites of a network to optimize query processing, and local backup copies are used to enable the recovery of data objects.

Using stable storage as an example, it has been shown that local backup copies can be saved by using a remote replica for restoring a damaged data object. In many cases, the method can be shown to be superior to the method of using local backup copies (Walter, 1983).

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1/24/84

INTERNATIONAL JOINT CONFERENCE ON ARTIFICIAL INTELLIGENCE

by William J. Clancey. Dr. Clancey is Professor of Computer Science at Stanford University.

The Eighth International Joint Conference on Artificial Intelligence was held in Karlsruhe, Federal Republic of Germany, in August 1983. It showed clearly that the field of artificial intelligence (AI) has matured to the stage of involving a wide variety of participants from many countries.

Several of the invited lectures and the panels were of considerable value to researchers interested in knowledge representation for teaching. J.S. Brown, for example, provided an excellent overview of qualitative reasoning. He compared the various approaches to qualitative modeling used, for example, by Forbus, Kuipers, and DeKleer and Brown, with the aim of identifying the essential power of each approach and thus isolating basic principles. He then developed his notion of the components of a device "performing computations" to "decide" what their next stage should be. This low-level, precise study of processes complements work on higher level diagnosis, such as that based on stereotypes of disorders. It can be expected that future models of expert knowledge will integrate both approaches.

Valuable invited lectures were also contributed by Barston on automatic programming and by Rosenschein on natural language. Barston's approach, for example, deemphasizes the role of logical deduction and programming knowledge in favor of knowledge of the task domain. Understanding the ways in which the actual problems to be solved shape the problem-solving procedures is central to other research on how correctness and efficiency constraints shape diagnostic strategy.

Several of the panels were also noteworthy. A panel on "AI and Databases" provided a useful tutorial; Reiter, Gallaire, King, Mylopoulos, and Webber all contributed lucid presentations. The problem of representation of databases is directly relevant, for example, to teaching diagnosis to medical students because search strategies treat knowledge of stereotype disorders as if they were represented in a well-structured database. Moreover, some of the work combining logical axioms for asking questions of a database and extending the relations it

explicitly records is directly analogous to the "metarules" used in medical diagnosis programs (e.g., see Davis, in press; Davis, Buchanan, and Shortliffe, 1977; Clancey, no date).

Another session was labeled "Cognitive Modeling," an area closely related to research sponsored by the Office of Naval Research. It included the following papers:

1. Logic modeling of cognitive reasoning--Hagert and Hansson (Sweden). This was an interesting attempt to express cognitive models in logic, particularly to show how changes in a subject's model of a problem can be expressed propositionally and contrasted with inferential changes within a given model.

2. Motives and emotions in a general learning system--Wallace (Australia). The key idea is that emotions mark a trace of experiences for later focus in learning. This has intriguing implications for teaching.

3. Artificial intelligence in the classroom--Bell (England). This was a report on using "Big Track," a programmable tractor in a classroom.

4. Modeling cognitive development on the balance scale task--Sage and Langley (US). Discrimination is used to modify rules for proper application; this idea seems to be fairly well established now.

5. Semiautomated analysis of protocols from novices and experts solving physics problems--Konst (The Netherlands). Initially, this work appears to be very competent, with an excellent motivation based on modeling expert/novice differences (see *ESN* 38-2:63-66 [1984]).

Another panel, on "Industrial Strength Knowledge Bases," was chaired by Kehler. My paper argued for developing better brittle systems in partial answer to J.S. Brown's characterization of expert systems. The argument is that causal models are incomplete in many areas for which we want to build advisors (medicine, economics, social science, command and control). Current systems are more brittle than necessary because their representations are inadequate. The weakness of the systems reveals itself in problems of maintenance, explanation, and multiple use (teaching, distributed problem-solving, encyclopedia). I presented examples from GUIDON and NEOMYCIN to illustrate the need for a principled source of expertise (relevant for evaluation) and factoring out kinds of knowledge. Many of the problems of acquiring, representing, and sharing knowledge relate to previous work in protocol analysis, programming language design, and databases. Other members of this panel were Friedland of the MOLGEN program, Reboh of the PROSPECTOR program, and Rosenberg. Discussions in this panel were particularly valuable for sharing quite different approaches to knowledge acquisition.

Other highlights of the conference were talks by R. Smith, who gave a coherent account of the oil-well log interpretation problem, and by J. McDermott, who presented an overview of expert systems research. "Computers and Thought," a lecture by T. Mitchell, provided a clear tutorial on his LEX learning program, with a good summary of the state of learning research. Many of his techniques and general observations are directly relevant to student modeling research and to investigations of how students learn strategies (which is what Mitchell is modeling). Others could easily incorporate his problem-generation heuristics in modeling programs in order to test the student in a way that will improve the program's model of what he knows. Also, the generalization hierarchy of problem features that LEX uses as terms in learned strategies correspond exactly to the "retrieval structure" that we have said interfaces strategies to domain knowledge (Larkin and others have made similar observations about physics problem solving).

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1/25/84

EARTH SCIENCE

OVERVIEWS OF GEOPHYSICS AT THE 18TH IUGG

by R.L. Carovillano. Dr. Carovillano is the Liaison Scientist for Space Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until June 1984 from Boston College, where he is Professor of Physics.

This article highlights invited, all-union lectures in geophysics presented at the August 1983 meeting of the International Union of Geodesy and Geophysics held in Hamburg, Federal Republic of Germany. The talks were by Prof. Raymond Hide (Meteorological Office, Bracknell, UK) on "Rotating Fluids in Geophysics and Planetary Physics"; Prof. J.C. Dooge (University College, Dublin) on "The Waters of the Earth"; and Prof. Seiya Uyeda (Earthquake Research Institute, University of Tokyo) on "Subduction Zones: Their Diversity, Mechanism and Human Impacts" (see also *ESN* 37-12: 452-453 [1983]).

Hide spoke on the properties of rotating magnetized fluids. Applications discussed were mainly for the earth and Jupiter. The surface magnetic fields of both the earth and Jupiter are approximately dipolar, though Jupiter's surface field is about 10 times larger than the earth's. The inclination of the dipolar axis is about 11 degrees for the earth and 10 degrees for Jupiter. Hide discussed the origin of the magnetic field (the so-called dynamo theory) and selected atmospheric effects.

The magnetic field of a planet is generated from electrical currents that are produced primarily from motions in the outer core of the planet. The cores of the earth and Jupiter have high electrical conductivity and high magnetic Reynolds number. The latter property is needed for the magnetic field to be strongly coupled to the fluid motions of the core and to be steady in time outside the planet. It is well known that the dynamo (or self-excited) magnetic field cannot be axially symmetric since such fields undergo rapid ohmic dissipation. Because the core is much smaller than the planet (e.g., half as large for the earth), the external field can be substantially axisymmetric and dipolar even though the core field is not. The core is very hot and its outer layers quite homogeneous, so that the magnetic field at the surface of the core would likely be much larger than the external field and much more complex (i.e., nondipolar). Observational information is difficult to relate to the core motions, and little can be said empirically about the core field.

When dynamical effects are considered, shear waves and inertial waves involve restoring forces because of rotational effects; elastic waves give rise to effects for the earth but are not useful for deducing the rotation rate; and Alfvén waves are nondispersive and can support shear.

In considering atmospheric applications, Hide displayed evidence for a 7-week oscillation in atmospheric data that may be a climatic effect. Hide stated that the Chandler wobble (i.e., the motion of the earth's rotation axis) can be explained as due largely to the differential rotation of the atmosphere and the transfer of angular momentum to the solid earth. The explanation does not require a core effect or an earthquake mechanism. Finally, Hide suggested that the red spot of Jupiter may result from the barotropic rotation of the atmosphere with controlled boundary heating and cooling. Other, far more exotic mechanisms are unnecessary. Rapid rotation and cooling at the boundaries will produce spots and other standing atmospheric effects.

In an entertaining and informative presentation, Dooge spoke about the waters of the earth. The hydrosphere is not a necessary feature of the earth, and its existence is even a bit unlikely in view of the origin and evolution of the earth. Thermal escape or loss of water would often be the more natural situation for a planet. An anomaly is that all three phases of water (solid, liquid, vapor) exist on the earth, because the surface temperature of the earth is just above the triple point of water. This is seen in the effective and actual surface temperatures of the terrestrial planets given in Table 1. The planetary atmosphere causes the difference between the effective and actual temperatures. The dramatic temperature difference for Venus is explained by the runaway greenhouse

Table 1

Surface Temperatures
(in degrees Kelvin)

	Mercury	Venus	Earth	Mars
Effective	442	317	267	216
Actual	442	739	288	219

effect. Because of its high temperature, the Venusian atmosphere contains only vapor. If the earth were only 5 percent closer to the sun, it too would experience the runaway greenhouse effect. Water originates from outgassing from the interior of a planet.

Dooge discussed water cycles that derive directly from geophysical factors and that are affected by factors such as population, economics, and politics. Estimates that may have large errors were given of the amount of water in the hydrosphere. The total amount is 1460×10^6 km³, of which about 94 percent is salt water. About 99 percent of the known groundwater is frozen (about 29×10^6 km³), although inactive underground sources, which may be as large as 56×10^6 km³, may greatly alter this estimate.

Hydrospheric models have been developed with diverse approaches, such as continuum mechanics, statistics, and use of a black box. Models are developed for different purposes, and some may be contradictory. The present norm is to develop new models (deterministic, stochastic, probabilistic) rather than to make objective comparisons of existing models. In discussing the development of ideas on catchment, both deterministic and *ad hoc* statistical theories were described. Catchment is important for understanding certain large-scale water flows and for predicting floods. Curiously, Dooge stated that new and useful catchment ideas need not follow the laws of continuum mechanics and seemed to advocate that approach. This perspective would appear to be at odds with the recent quadrennial report of E.F. Wood (Princeton University), who reviewed scientific advances in surface water and groundwater hydrology and the developing trends for a more scientific basis for engineering hydrology (Wood, 1983).

Uyeda provided a wealth of information on earthquakes, reviewed current ideas on subduction, and emphasized the need to identify basic principles. He listed the largest earthquakes in history; the two most energetic were in 1960 in Chile (10^{19} J) and in 1964 in Alaska (about 5×10^{18} J). The San Francisco earthquake of 1906 was much smaller than these.

Earthquakes were discussed in terms of size, underlying plate characteristics, and possible factors affecting dynamics. Earthquakes of the Chilean type are the largest; the Mariana type are relatively smaller. The Andes are located above the collision zone of the American plate and the underthrusted Pacific plate. The mid-Atlantic ridge is located essentially at the junction of the American and African plates. A heat flow of 1 W/m² exists in the Mariana trough. The mineral deposits that are known to be aligned with North American subduction zones are curiously lacking in Japan. On the development of subduction, Uyeda suggested that motion of the upper plate is large compared to that of the underthrusting plate. The latter is probably connected or anchored to the earth's mantle. The motion of the mantle is poorly understood, but the implication would be that it is much slower than plate motion. A principle in subduction is that the region above the subducted zone is heated and softened by the collision of the plates, and the harder lithospheric plate underthrusts. This configuration should be used to consider the subsequent dynamics and heat escape, such as from volcanoes, following the collision.

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12/22/83

MATERIAL SCIENCES

IAEA GROUP EXAMINES STEELS FOR NUCLEAR-REACTOR PRESSURE VESSELS

by L.E. Steele. Mr. Steele is Head, Thermostructural Materials Branch, Material Science and Technology Division, Naval Research Laboratory, Washington, DC.

The "Participants and Consultants Meeting on International Atomic Energy Agency Coordinated Research Program, 'Analysis of the Behavior of Advanced Reactor Pressure Vessel Steels Under Neutron Irradiation,'". was held in Vienna, Austria, from 13 through 15 December 1983. This conference and another, in June 1983, were held to hear final reports on the second phase and to develop a plan for the third phase of a research program that began in the 1970s.

More than a decade ago, the International Atomic Energy Agency (IAEA) established an International Working Group on the Reliability of Reactor

Pressure Boundary Components. The group is concerned with the problem of radiation embrittlement of primary reactor vessels exposed to high-energy nuclear radiation.

As part of this emphasis, a Coordinated Research Program was initiated with a multinational group of participating institutes. An early effort, lasting from 1972 to 1976, was called "Irradiation Embrittlement of Pressure Vessel Steels," and became known as Phase 1. It focused on one steel from the US Oak Ridge National Laboratory; the objective was to verify that the evaluative technologies involved were adequately uniform or standard to permit direct comparisons among results from eight national programs. This objective was achieved, but the results demonstrated that the steel made in the late 1960s was subject to radiation embrittlement. This led logically to Phase 2, which was called "Analysis of the Behavior of Advanced Reactor Pressure Vessel Steels Under Neutron Irradiation." The second phase was begun in 1977 and completed in 1983.

The goal of Phase 2 was to demonstrate that knowledge has advanced to the point that steel manufacture and welding for nuclear technology can routinely produce steels for reactor pressure vessels of high radiation resistance. The program results on eight steels from 14 institutes in eight countries have validated the goal. The steels--involving forgings, plate, weld, and weld heat affected zone of two basic compositions--met American Society for Testing and Materials specifications A508 (forging) and A533-B (plate), but with special limits on residual element content. The steels were made in France, Germany, and Japan. It was learned that steels manufactured with particular attention to specification to control elements such as copper, phosphorus, and nickel--that is, the "modern" or "improved" steels--showed high resistance to neutron irradiation embrittlement. Detailed reviews and analyses of results were presented and included studies of varying temperatures, annealing to correct embrittlement, fracture mechanics evaluation, and examination of mechanisms of radiation embrittlement as well as conventional pre-post fracture data. The results were analyzed to assess not only current international understanding of the problem, but also the need for additional study.

Besides reviewing the results of the Phase 2 study, the consultants' conference, recognizing some critical unanswered questions, agreed to advance a proposal for Phase 3--"Optimizing of Reactor Pressure Vessel Surveillance Programs and Their Analysis." The primary objective will be to optimize reactor pressure vessel surveillance programs and their analysis; in addition, Phase 3 will have the following subordinate goals:

1. Optimization of the means for measuring fracture resistance
2. Establishment of correlative methods for measuring irradiation response by using different mechanical tests
3. Understanding of the mechanisms responsible for embrittlement
4. Establishment of means for ameliorating embrittlement.

For the purposes of this study the conference participants accepted the following definition of surveillance: "the periodic assessment of the condition of a nuclear power reactor vessel with the view toward assuring its structural integrity." In addition, participants accepted a series of expected results:

1. Clarification of fracture-toughness-test methodology, with the resulting identification of a preferred approach.
2. An accepted basis for correlating conventional notch impact tests and several alternative fracture toughness tests now included in surveillance programs.
3. An improved basis for reassuring the fracture resistance of a pressure vessel. A better basis for using research results from large specimens and model vessel tests to validate small-specimen test results.
4. A systematic study of the mechanisms of steel embrittlement, especially the role of constituent elements.
5. An evaluation of post-irradiation heat treatment for reducing embrittlement with identification of time, temperature, steel sensitivity interaction.
6. The influence of environmental factors, besides radiation, which may affect vessel steel properties.
7. The merits of alternative neutron dosimetry procedures.

To support this effort, 32 steels from four countries--France, Germany, Japan, and the US--were offered for the study. National representatives from 12 countries agreed to a massive research

undertaking to meet the goals and expectations cited above. The countries included Argentina, Czechoslovakia, Denmark, Finland, France, Germany, India, Japan, Spain, Switzerland, the UK, and the US. Others, not present but expressing strong interest, were the European Economic Community, The Netherlands, and the USSR.

1/24/84

NATIONAL AEROSPACE LABORATORY, THE NETHERLANDS

by R.W. Armstrong. Dr. Armstrong, formerly at ONR, London, is on subbatical leave from the University of Maryland for the 1984 spring term as Visiting Fellow, Clare Hall, University of Cambridge, UK.

Civilian and military aerospace projects of the Nationaal Lucht- en Ruimtevaartlaboratorium (NLR), known as the National Aerospace Laboratory, are included within four divisions: Aerodynamics, Avionics, Satellites, and Structures and Materials. The total laboratory involves about 500 persons in Amsterdam and 250 in Emmeloord. The NLR Administrative Board office is at Delft, and a test range facility is on the northwest coast at Texel. The laboratory will be consolidated eventually at Emmeloord, where a new, large, wind-tunnel facility, undertaken as a joint project with the Federal Republic of Germany, is very near completion.

The Structures and Materials Division employs 45 persons at Emmeloord in four departments: Loads, Structures, Materials, and Testing Facilities. H.P. van Leeuwen is head of the division. Research activities include: load specification, structural response, fatigue properties, fracture and fractography, stress corrosion, hydrogen embrittlement, high temperature properties, materials evaluation, composite materials, and failure analysis and nondestructive testing.

G. Bartelds is head of the Structures Department, which is soon to be substantially enlarged by increasing the size of the composites research effort. The buckling behavior of composite components can be a limiting design feature, so a number of finite-element programs have been developed to describe the behavior. J. Wiggenraad has utilized the programs to investigate the influence of coupled bending and torsional stresses on the buckling load of orthotropic plates. Other finite-element analyses have been made of fracture-mechanics cracking problems. P.J. Sevenhuijsen has worked for more than 10 years on the use of grids and photonics for the measurement of structural deformations, particularly at crack tips. A laser-grating method has been developed for reading photographic records of deformation grids at crack tips. A report is in progress on the latest results of achieving 50-microstrain resolution on spatial elements as small as 0.5 mm achieved with the laser-grating method; the results compare with 250 microstrain measured at a spatial resolution of 0.1 mm for an elementary method of optically magnifying the grid record (Sevenhuijsen, 1984).

W.G.J. 't Hart has investigated the tensile failure, residual strength, and fractography of carbon/epoxy laminates and Kevlar-carbon/epoxy hybrid composite materials. He participated in a 1-day national meeting in Delft on 18 November 1983 to discuss the theory and applications of new strong fiber materials. M.G. Northolt (Akzo Research Laboratories, 6800 AB Arnhem) presented work on aramid fibers such as poly-p-phenylene terephtalamide, poly-p-benzamide, and poly-p-p^1-benzanilidene terephtalamide materials (Northolt, 1983). A.J. Pennings (State University of Groningen, 9747 AG Groningen) described work with colleagues on obtaining high molecular weight polyethylene fibers with a tensile strength of 5 GPa and Young's modulus of 200 GPa (Pennings, Smook, de Boer, Gogolewski, and van Hutten, 1983).

Vogelsang and Gunnink (1983) gave an interesting paper on the development of a new family of aramid aluminum laminate (ARALL) composite materials developed in a joint project between the Department of Aerospace Engineering, Delft University of Technology, the Fokker Aircraft Company, the NLR, the ENKA (Akgo) Company, and the US Alcoa and 3M companies. ARALL is fabricated from thin, adhesively bonded, high-strength aluminum sheets and strong, unidirectional aramid fibers impregnated with metal adhesive. The fabricated material is prestrained after curing so as to produce a compressive residual stress in the metal sheets. The basic mechanical properties are very significantly superior to 2024-T3 aluminum; especially excellent fatigue properties are obtained.

W.G.J. 't Hart is enthusiastic about the ARALL material and the possibility of developing further materials

along this line. He presented the paper "Properties of Modern Fiber Reinforced Plastics." Also, he mentioned the formation of a group on aerospace research and technology in Europe (GARTEUR), composed of the NLR, the UK Royal Aircraft Establishment (RAE), the French Office National d'Études et de Recherche Aerospatiales (ONERA), and the German Deutsche Forschungs-und Versuchsanstalt für Luft-und Raumfahrt e.V. (DFVLR). Composites research apparently will be an important activity within GARTEUR.

The Materials Department at NLR is headed by R.J.H. Wanhill, who also has a strong research interest in engineering design based on the fracture-mechanics properties of materials. With H.L. Ewalds, Wanhill has produced the book *A Basic Course in Fracture Mechanics*, soon to be published in The Netherlands by Delftse Uitgevers Maatschappij b.v. and in the UK by Edward Arnold Publishers. Materials evaluation for civilian and military aircraft structures is an important activity at the NLR. Wanhill (1982) has reported on the role of fracture mechanics considerations in materials selection and structural design. The methodology has been applied to structural and fatigue considerations in the design of rotor blade and shaft assemblies for modern windmills (Wanhill, 1984b). Other current projects relate to the threshold for fatigue damage from short cracks (Wanhill, 1984a) and to the development of advanced aluminum alloys by powder metallurgical methods (Wanhill and Schra, 1984).

Evaluation of high-temperature materials, such as aircraft turbine components, is an important, long-standing research activity at NLR. Kolkman and Wanhill (1982) have reported on the combined creep and fatigue behavior of cast René 80 nickel-base superalloy material tested in air. They found that prior creep deformation could have a beneficial effect on the high-cycle fatigue life of the material and *vice versa*. Excellent transmission electron microscopy (TEM) results were obtained of annealed dislocation networks which formed around ordered Ni_3Al particles during creep deformation and subsequently thwarted deformation from occurring in fatigue; and, likewise, an increased density of matrix dislocations due to the high-cycle fatigue damage hindered subsequent deformation in creep tests.

Kolkman (1982) has done fundamental TEM work on the selection of slip systems in thin copper single-crystal foils strained in the electron microscope. The movement of more than 1500 dislocations was observed in 23 specimens and correlated with glide system rotations determined from sequential electron-diffraction patterns or from the surface movement of graphite particle markers. The analysis of results led to the observation that the activated glide systems were those with a slip direction in two glide planes making the smallest angle with the foil plane. The expertise developed in the dislocation study has been applied to specifying dislocation structures in even more complex situations than described above for the combined creep and fatigue behavior of René 80. For example, 't Hart, Kolkman, and Schra (1982) have reported observations of the precipitate and dislocation structures obtained in corroded 2024 (AlCuMg) and 7075 (AlZnMgCu) alloys subjected to variable quenching treatments in the form of Jominy test bars, which are normally used for testing the hardenability of steels.

Kolkman (1982) has reported on the NLR test rig employed to measure combined corrosion-erosion of turbine blades or vanes in the compressor head of jet engines (see Figure 2, *ESN* 38-1:29 [1984]). Kolkman and Mom (1984) have reported more recently on tests of the aqueous electrochemical corrosion occurring in the compressor sections of land-based gas turbines, and of fighter aircraft and helicopter jet engines. In addition, the NLR has a burner rig for testing blade sets in the particularly severe environments encountered by aircraft flying in Western Europe.

Figure 1 shows the schematic arrangement for high-temperature testing of turbine blades and coatings in a burning atmosphere; pollutants can be added, and the rig can induce thermal stresses. Mom and Kolkman (1984) have reported test results on the oxidation and hot (alkali metal sulphate) corrosion behavior of coated turbine blades. Diffusion coatings, metallic overlay coatings, and ceramic coatings were assessed. Particular metallic overlay systems were recommended: NiCoCrAlY for land-based aircraft; and Pt-aluminides and CoCrAl for marine (ship and aircraft) and industrial turbines. The subject of gas-turbine materials continues to be an extremely active area of materials research in Europe (see *ESN* 37-1:21-24 [1983] and 37-7:266-271 [1983]).

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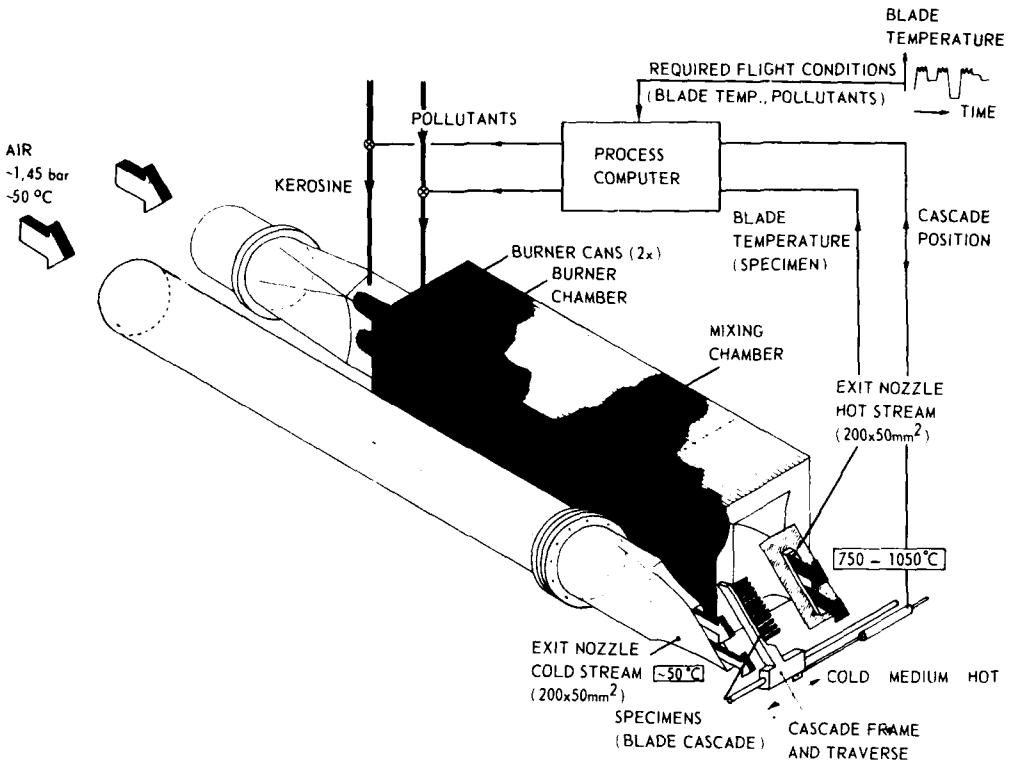

Figure 1. NLR high-temperature burner rig with pollutant and thermal stress capability for testing turbine blades and coatings.

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12/21/83

OCEAN SCIENCES

RHYTHMIC SHORELINE FEATURES ON THE HIGH-ENERGY GRAVEL BEACHES OF IRELAND

by Robert Dolan. Dr. Dolan is the Liaison Scientist for Geology and Oceanography in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until September 1984 from the University of Virginia, where he is Professor of Environmental Sciences.

One of the most significant developments in coastal science over the last two decades has been the effort by many geologists and oceanographers to explain the regular and periodic variations in crescentic landforms that occur along sedimentary coasts.

These landforms range in size from beach cusps (tens of meters) to capes (100 km). Explanation for periodicities in coastal landforms (cusps, bars, overwash patterns, and so forth) and associated processes have in recent years focused on the role of standing waves, or edge waves. There may, however, be several other processes involved, including meandering longshore currents and the distribution of rip currents. One process may trigger secondary processes, which in turn produce the rhythmic topography. Paul Komar (Oregon State University) said in a talk presented in London in 1982 that "...the fascinating aspect of this subject is that some of the features have distinctly origins, even though the fin shorelines are similar in sha always in scale. This is an example of equifinality, whe larly appearing features are by different processes. Ho investigated carefully, some crescentic shoreline forms irregular [that] little if a can be deciphered. At other rhythmic pattern is regul uniform spacing and horizonta between successive features."

Some of the pioneering r rhythmic shoreline features carried out in the UK. Spe the work of M.S. Longuet-Hig Bowen, and D.A. Huntley rep important component of the discovery for this subject. article I'll report on a pro to get under way in Norther that will focus on rhythmic features occurring on grave that are frequently subjecte tremely high wave action surge (Figure 1).

Rhythmic shoreline especially beach cusps, can b any type of beach sediment, ra cobbles to shingle and sa morphology of the cusps deper size of the beach sediment, slope, tidal range, and wave The best examples of cusps gravel beaches with low tid There seems to be a strong c between spacings and wave hei the cusp fields reaching max in areas of high waves and min in areas of low waves.

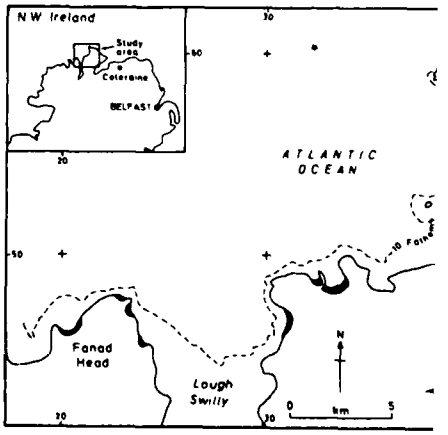

Figure 1. Field research site by Orford and Carter.

Julian Orford (Queen's University, Belfast) and William Carter (New University of Ulster, Coleraine) have collaborated over the past several years on research dealing with the morphology of high-wave-energy gravel beaches. Gravel and cobble beaches and barriers are much more common along the coasts of Ireland and the UK than in the US, and rhythmic features on the gravel beaches are the rule rather than the exception.

As indicated earlier, the cusp-production theory that has received the most attention in recent years emphasizes the roles of standing waves and of edge waves. In his 1982 talk, Komar pointed out that as early as 1937 a European investigator (B.G. Escher) "...suggested that rhythmic shoreline forms were produced by standing waves in the surf zone that are at right angles to the incoming waves. Where the two sets of waves (incident waves and standing waves) supported one another the resulting higher wave swash eroded bays, and where opposed the swash was lower and cusps horns formed."

According to Komar's description, edge waves are trapped waves along the ocean edge, held there by the seaward slope of the bottom. They can best be thought of as waves that reflect from the shoreline, refract as they move seaward such that the angle they make with the shoreline progressively increases, just opposite to the refraction of incoming waves, where the angle progressively decreases. With a certain period and bottom slope, it's possible that the wave will refract until it bends back in, returns to the beach, and reflects; then the process repeats. Therefore, the wave is trapped to the sloping beach and does not radiate energy offshore.

Edge waves can be progressive or standing. For standing edge waves, there are alternate positions of nodes where there is no observable up-and-down motion of the water surface, and there are antinodes where the full edge-wave height is observed as the maximum up-and-down motion.

Field and laboratory investigators have detected edge waves with periods ranging from those of the incident waves (3 to 15 seconds) up to 300 seconds. Thus, with a length that can range from centimeters to kilometers, edge waves have the potential for explaining rhythmic shoreline features over a similar size range. With these dimensions the amount of energy in an edge-wave field may exceed the energy of the incoming incident waves. Two British oceanographers, David Huntly and Anthony Bowen, were the first to record measurements of edge waves on ocean beaches.

The development of edge waves increases with incident wave height, reaching a maximum amplitude at the shoreline. The actual product is the periodic elevation of the still-water level at places along the shoreline. Superimposed on these periodic high and low water levels are the incident waves (14,000 to 16,000 per day), which contribute additional "energy" to the inshore sediment transport processes. The results are higher elevation and deeper landward penetration of sediment transport processes at regular intervals along the shoreline (Figure 2). Some investigators are convinced that even modest elevations of the still-water level along the coast contribute to predictable patterns of storm surge penetration.

To make what I believe is the next advance in coastal process research, Carter and Orford will investigate the magnitude and frequency of trapped wave activity on the Irish beaches. Although they haven't any field measurements of edge waves, the presence of cusps on

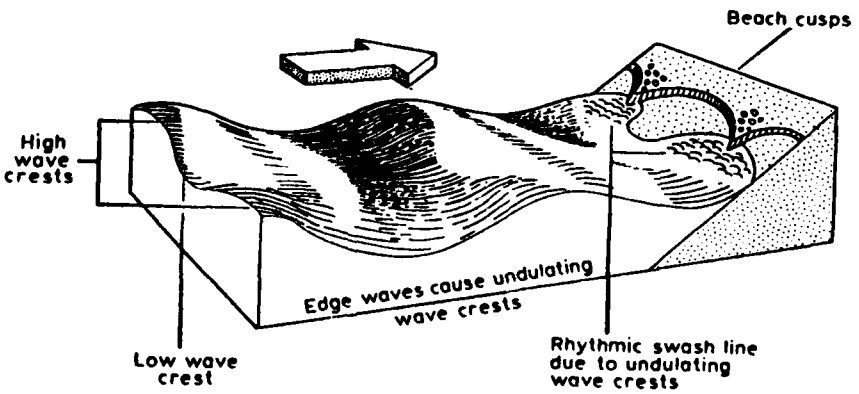

Figure 2. The relationship between edge-waves and beach cusps.

most of the beaches provides strong evidence that the waves exist. Carter and Orford have also identified a spatial arrangement of washover throats and fans which appears to be correlated with subharmonic edge waves excited by 9- to 11-second incident storm waves. Smaller (10 to 20 m) cusp spacings on the beach faces also occur--usually out of phase with the washover throats; this, of course, presents a problem of explanation in terms of trapped waves. In a forthcoming paper Carter and Orford conclude, speculatively, that a hierarchy of storm-based edge wave modes dominates the pattern of morphology on these beaches. If this proves to be correct, their research will represent a major step in the explanation of rhythmic shoreline features.

I have visited the field sites Orford and Carter will use in their investigations. The embayed coast around Northern Ireland includes about 20 gravel beaches that are 100 m to over 1 km in length. The slopes are steep, and I have seen a hierarchy of cusps (up to four sets) with wavelengths between 10 and 100 m and amplitudes between 1 m and 3 m. The spring tide range is only 3.7 m, and the estimated tidal surges rarely exceed 0.5, yet the vertical range of the active subaerial beach change in places is up to 14 m. This strongly points to either very high breaking waves or considerable local supra-elevation of mean water levels, or a combination of both.

There will be a number of difficulties in carrying out field studies at these sites. Surf zone instrumentation will be exceedingly difficult given the range in water levels and size of the wave, and working along this coast during the winter will be a real test of the researchers' dedication. However, they are enthusiastic and confident; the primary question to date is funding. Support for any research in the UK today is extremely difficult to obtain, regardless of the potential contribution of an investigation.

The specific objectives of Orford and Carter's research are:

1. To examine the potential magnitude and frequency of trapped waves on reflective beaches over a range of wave conditions at a number of gravel-dominated beach/barrier sites. Of particular interest will be the development of cellular flows in the nearshore zone through the tidal stages.

2. To define conditions resulting in the formation of cusps, especially the limitations of beach height and width on cusp geometry (spacing and amplitude). In this context cusp sedimentation patterns (textural grading, size/shape/density particle discrimination, etc.) will be investigated. They also will examine the antecedent morphology required for overtopping and overwashing in the presence of trapped waves.

3. To consider the role and effect of swash zone cusps on beach and barrier dynamics, and to examine feedback between cusp morphology and edge-wave excitation.

4. To investigate sedimentary products associated with extreme water levels and to relate these to the long-term morphodynamics within the context of changes both in sea levels and in sediment budgets.

Orford and Carter welcome visitors to Northern Ireland and would look favorably on potential collaborative research programs.

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1/20/84

STORM AND CURRENT PREDICTION AT IOS BIDSTON

by Robert Dolan and D.R. Barr. Dr. Barr, formerly at ONR, London, is Professor of Statistics and Operations Research at the Naval Postgraduate School, Monterey, CA.

The UK's Institute of Oceanographic Sciences (IOS) has a staff of about 370 at four sites in central and southern England. The groups at Wormley and Hambledon work on deep-ocean physics, chemistry, geology, geophysics, and biology. The groups at Taunton are concerned mainly with sedimentation and applied wave research. At Bidston, near Liverpool, the program is directed toward studies of oceanic and shelf tides and the dynamics of shelf seas.

On a recent visit to the Bidston Observatory, we talked to several scientists about their current work on the analysis of extreme sea levels, research on large-scale movements of the sea around the UK, the prediction of storm surges, and the modeling of shelf currents.

Ian Vassie and a colleague, D.T. Pugh, are analyzing extreme sea levels, using data on sea levels (some for 125 years) from a number of ports along the southern coast of England. It's well known that the sea level along the southern UK coast is rising at a rate of about 2 mm per year, a process which is reflected in long-term changes in high and low water heights. This has been one of the motivating factors for construction of the Thames Barrier near London, as ever higher and more frequent flooding has been occurring in the Thames Estuary (*ESN* 37-1:27-30 and 37-12:450-452 [1983]). There have been attempts to model extreme sea levels using fitted asymptotic extreme value distributions as well as various time-series models. However, extreme sea levels are caused by a complex interaction of tides, waves, surges, and weather factors. There's also considerable uncertainty in sea level measurements made in conditions which often accompany extreme levels.

Vassie told us of the approach he and Pugh have been using to model extreme sea levels. With this approach, which he calls the "joint probability" method, separate estimates are made of the distributions of the tidal and surge components (usually based on relatively short periods of data); the results are combined by numerical convolution to obtain an estimate of the combined sea level distribution. From the latter, various inferences can be made about extremes, such as predicting the height of the 100-year extreme sea level. Vassie has compared such prediction with levels actually recorded in data sets spanning longer periods of time--with favorable results, he says. He claims this method has an advantage over other approaches because it's applicable to limited data situations, although it demands better observational accuracy and greater amounts of data processing. Practical estimates can be obtained with only a single year's data, he says. In taking a simple convolution of tide and surge distributions, there is no consideration of interactions between the two; Vassie is currently extending his approach to include dependencies between the two components. The results from this method are expressed as return periods, the most common form of conveying information about distributions to engineers and designers.

These return-period statistics have important bearing on engineering and planning. For example, IOS Wormley has developed similar return values for wave heights. At times during winter storms oil platforms in the North Sea are hit by waves between 15- and 20-m high--as tall as a six story building. However, once or twice during its life expectancy, the platform may experience a wave 25 to 30 m high. Drilling and production are moving to the open North Atlantic--the West Sheltland Shelf, for example. There, platforms occasionally might be hit by waves of 35 to 40 m--as high as a 12-story building.

Oil platforms for the North Sea have to be built to withstand these giant waves. In UK waters the platforms are designed against the 50-year return value of wave height, which is the height that's exceeded on average once every 50 years. An estimate of this value, which depends upon the location and exposure of the site, is required by the designer of any offshore structure. The cost of overestimating, and building a platform too high, is about $1 million per foot. Underestimating may have even higher costs.

The IOS method of determining the 50-year return value of wave heights is essentially the same as the method used to estimate return intervals for storm surge. IOS scientists use wave heights recorded at three hourly intervals for a year or more. A statistical distribution, such as log-normal, is fitted to the wave-height data by calculating cumulative probabilities and plotting them on graph paper, which is scaled so that the chosen distribution is represented by a straight line. A line is

then fitted through the data points, sometimes through only the higher values, and extrapolated to the probability of the 50-year return value (given by $1-\frac{1}{N}$, where N is the number of three hourly values in 50 years; i.e., N = 1,461,000). Several distributions are tried, and the one giving the best fit straight line is used. If data for at least 5 years are available, uncertainty concerning the distribution of wave height can be avoided by using extreme value analysis. Wave data for 5 years or more are now available from several sites around the UK.

The return-interval wave-height values produced by the IOS have been used for design purposes throughout the UK sector of the North Sea during the last decade. No major errors have become obvious so far. Structural fatigue has been a problem on some platforms, but not damage from unexpected very large storm waves. However, with the development of new structures for use in the deeper and more exposed waters of the northern North Sea, there's even greater investment and concern for safety, so further research is under way at IOS to improve the theoretical basis for estimating return wave heights.

As a part of these studies of extreme wave heights and storm surges, the IOS has recently revised its map showing 100-year extreme storm surge heights for the North Sea and adjacent waters (Figure 1).

The scientists at IOS Bidston have also investigated the relationship of mean sea level around the UK to the land leveling established by the Ordnance Survey. Daily mean levels in the North Sea have also been used based on the altimetry from the Seasat satellite, in collaboration with a German geodetic research group. Several measuring exercises in shallow seas have included sea level records from specially installed tide gauges as well as arrays of current meters, and these have been used to explore relationships between mean sea level and current circulation.

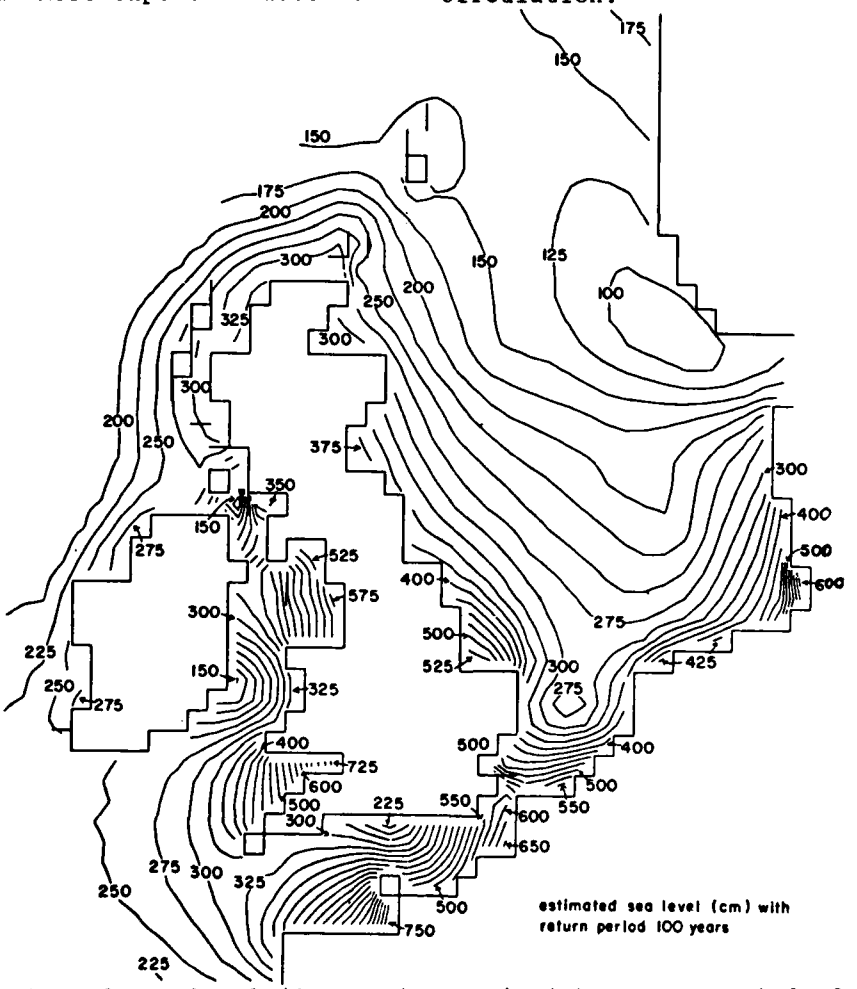

Figure 1. Estimated sea level (in centimeters) with return period of 100 years.

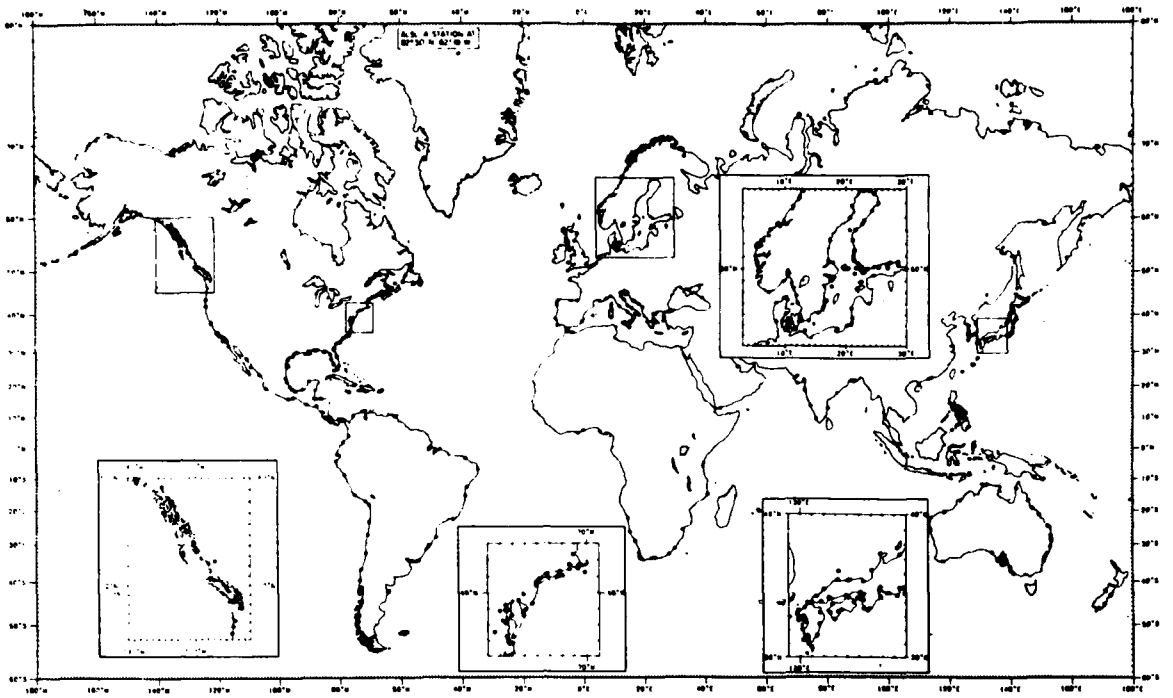

Figure 2. Global network of stations for which data are published by the Permanent Service for Mean Sea Level.

The international Permanent Service for Mean Sea Level has been based at Bidston since 1933. Monthly and annual mean data from all over the world are collected and stored there, and research is carried out on secular trends (Figure 2). Figure 3 provides a comparison of sea level curves for a UK site (Newlyn) and other sites around the world. Worldwide it seems that sea level is, indeed, gradually rising.

The IOS research includes extensive work on modeling processes in the coastal waters around the UK. This stems from a program to develop a national computerized system for forecasting coastal sea floods, especially at the southern end of the North Sea, where storm surges are high (see Figure 1). After more than 15 years of research, the IOS model has been accepted by the UK's Meteorological Office for operational running during the stormy season as an adjunct to the statistical methods employed by the Storm Tide Warning Service.

Among the most interesting projects under way at IOS Bidston is development by David Prandle of a two-dimensional numerical model to simulate long-term mixing in the coastal waters over the northwest European continental shelf. The model includes a tidal- and wind-driven component but no density-driven currents. The tidal component corresponds to the residual circulation

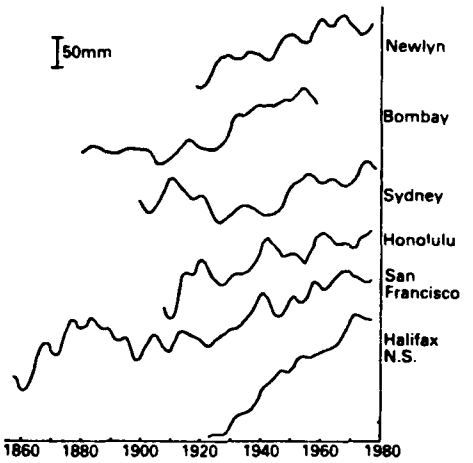

Figure 3. Trends in mean sea level relative to local land level at six of the 1142 tide-guage data stations handled by the Permanent Service for Mean Sea Level at Bidston.

extracted from a nonlinear model of the propagation of the predominant lunar constituent. The wind-driven component is derived by a summation of the steady-state response of a linearized model to winds from the west and south.

Prandle found similarity between the circulation patterns associated with these three residual components. This similarity is closest in the deeper areas of the shelf seas and suggests that such flows are close to a geostrophic balance with consequent topographic steering. Prandle established the validity of the calculated long-term circulation by comparing his results with similar modeling studies, direct measurements of long-term flows, and mean sea-level variations.

Prandle developed a mixing model from this hydrodynamic model. He found that in the mixing model the use of residual flow components, as opposed to instantaneous currents, prevents excessive numerical dispersion. He then derived optimal values of the turbulent dispersion coefficients by comparing his model simulations with the spread of Cesium 137 discharged from the Windscale nuclear reprocessing plant. Determining these coefficients was the only tuning process he used in the study. He stressed that the good agreement between model results and observations was not a consequence of careful tuning.

Cesium 137 has been discharged from Windscale into the Irish Sea for over 20 years; its spread has been carefully monitored by the UK Fisheries Radiobiological Laboratory and the Deutsches Hydrographisches Institut in Hamburg. Surveys by the organizations show that the Cesium leaves the Irish Sea, follows the Scottish coast into the North Sea, then ends up in the fjords along the Norwegian coast. Since Cesium remains in suspension for a long time, its spread is an ideal tracer experiment for development and evaluation of the IOS simulation models. The model developed by Prandle reproduced both spatially and temporally the observations in the field. At the end of the transport route along the Norwegian coast, observed concentrations of Cesium were reproduced to within about 20 percent. This accuracy may be viewed against a dilution rate of more than 20 relative to concentrations near the source (the North Channel) and a total transit time of up to 6 years. We add, parenthetically, that the route travelled by the Cesium is also the pathway for spawning of several species of important commercial fish important in the European markets.

The distribution of Cesium and other material within the North Sea is primarily determined by the pattern of advective transport, predominately wind driven. However, since the time scales for mixing are in terms of years, the distributions are related to the mean wind stress averaged over periods of 3 months or longer. Thus, the large-scale mixing pattern is only indirectly related to the influence of individual storms.

1/23/84

PHYSICS

INTERNATIONAL CONFERENCE ON ACOUSTIC EMISSION AND PHOTO-ACOUSTIC SPECTROSCOPY

by Chester McKinney. Dr. McKinney is the Liaison Scientist for Underwater Acoustics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until September 1984 from the University of Texas at Austin, where he is Senior Research Scientist at Applied Research Laboratories.

A conference on acoustic emission and photo-acoustic spectroscopy was held at Chelsea College, University of London, from 19 through 21 December 1983. It was sponsored by the Institute of Acoustics and was organized and chaired by Dr. R.W.B. Stephens, the reigning grand old man of British acoustics. The meeting might well have been titled "Talking Materials and Thermal Waves."

The conference was international in scope, with seven countries represented among the 41 registrants. However, it was largely a UK meeting (26 registrants), followed distantly by the Federal Republic of Germany (4), France (3), Italy (3), Sweden (2), the US (2, including myself), and Japan (1). Origins of the 25 papers (all in English) were in about the same ratio as attendants. About half were from universities and the rest were equally divided between industry and government activities. The papers were almost entirely of an experimental or hardware-technique nature. Applications were stressed much more than basic research. The papers are scheduled to be published as a conference proceedings

in March 1984 by the Institute of Acoustics, 25 Chambers Street, Edinburgh EH1 1UK, Scotland.

Acoustic Emission

Acoustic emission (AE) is a fairly new subject in the very old and broad field of acoustics. It has been defined as a transient elastic wave generated by the rapid release of energy within a material. Earthquakes clearly would qualify under that definition, but AE, in the usual context, deals with much smaller bodies than the earth. Basically, most solid materials, when subjected to stress, tend to "talk" or emit ultrasonic sounds. Something within the material must move. This movement may be due to stresses such as external bulk forces, internal strain release, corrosion, or magnetic forces. The emitted frequencies cover a very wide range and are determined by the speed and size of the movement (e.g., the length of a crack). Most of the papers at this meeting dealt with frequencies from about 20 kHz to 1.0 MHz. However, some processes occur in times as brief as 40 ns, giving frequencies as high as 25 MHz. The acoustic signals are detected by means of electroacoustic transducers (usually piezoelectric ceramics), coupled to an external surface of the material by means of a grease coating, by magnets, or both. Typical emissions result in the generation of a variety of compressional, shear, and surface waves. These waves travel with widely different speeds and are likely to undergo multiple reflections before reaching the transducer.

The typical transducer output is very complex since it is the convolution of the acoustic source function, propagation characteristics, and the transducer transfer function. However, much useful information concerning the original source can be derived by analysis of the signal. Commonly used measurements include: (1) a count of the number of AE events, (2) the duration of an event, (3) the number of times the signal exceeds a given threshold during an event (called ring count), (4) average event energy, (5) peak amplitude and distribution of amplitudes, (6) event amplitude rate of rise, (7) slope of the event decay, and (8) the frequency spectrum. Not all AE instruments measure all these features. At present a considerable amount of AE application work is qualitative and empirical; through experiments and observations it has been learned that certain AE signatures correlate with certain internal structures and behavior.

Joseph Kaiser, a German, may be considered the father of modern AE. In the early fifties he discovered that: (1) certain materials, when placed under stress, emitted sounds which (with suitable high pass filtering to eliminate masking low frequency noise) could be detected, and (2) these sounds related to internal events such as cracking. Activity in the US increased rapidly in the sixties, due in a significant part to the work of Hal Dunegan. AE moved from science to application very quickly as another technique for nondestructive testing (NDT). One of the early applications was to listen for AE during the cycling of a storage tank from low to high pressure. Some of the advantages of AE for NDT include the following: (1) relatively simple, inexpensive, and rugged equipment is used; (2) a single sensor can monitor a large volume or area (but generally multiple sensors are employed), (3) continual monitoring and automatic alarm are very feasible, (4) results, at least in limited form, are available in real time. Generally AE instruments are used to complement other NDT devices. For example, AE can be used to detect, and coarsely locate, a number of suspected flaws in a material. With this rough survey information, x-ray or ultrasonic echo ranging instruments can then be used to examine the suspect areas in fine detail.

AE is a passive listening technique; detection of an internal sound source is much easier than location. In general a single sensor cannot provide source location, even coarsely, unless the sensor is mechanically moved over the surface, searching for the point of maximum signal. This is a slow process; the usual arrangement is to use a number of sensors, distributed over the surface of the material under investigation. By comparing relative amplitudes and relative times of first arrival (or by correlation) one can estimate the AE source location. This technique does not provide information on the depth of the source; but for many cases this is not a critical point, since often the material is in sheet form (i.e., the geometry is essentially two dimensional).

Even with multiple sensors, source location is fairly coarse since materials are frequently anisotropic, and the nature of the signals received at the different sensors differs more than in time of first arrival. Also the wave propagation speed to the various sensors may vary significantly. H.A. Crostack (University of Dortmund, Federal Republic of Germany [FRG]) described a method

which improves on the accuracy of source location. His method involves the use of several sensor probes distributed over the material surface, with each probe being composed of four detector elements, closely spaced. The signals received by the elements are essentially the same, except for slight differences in times of arrival. The propagation paths for the four signals are nearly the same. By measuring the time of arrival (by cross correlation), Crostack determined the direction to the source with fairly good precision. Then by using two or more multiple-element probes, he located the source by triangulation (i.e., by geometry). The examples he showed were for small probes, a few millimeters in size, on a plate 2 m by 2 m. He used frequencies of 0.5 and 1.0 MHz. The results were quite good.

In-situ calibration of AE transducers is highly desirable. Standard calibration signals are generated by breaking the point of a lead pencil (of known characteristics) or a capillary tube against a surface of the material being tested. R.G. White (Loughborough University, UK) described his work on *in-situ* calibration techniques, which included using a laser interferometer to measure surface motion.

N. Higo (Tokyo Institute of Technology, Japan) gave an excellent paper on the use of AE to study the martensitic transformation in stainless steel. This is a phase transition which occurs within a limited temperature range as certain steels become very hard and brittle under stress. The duration of AE events gave information on the rate of transformation, while the spectrum analysis of the AE signals allowed him to estimate the volume of the individual transformations. The frequency range was from 200 to 1000 kHz, and the measured rise times were in the order of 1.0 μs. The AE sources were very small, esentially point emitters.

Several papers described the use of characteristic AE signatures to detect and locate faults in materials ranging from small to very large. D. Bell (British Ceramic Research Association) described the use of AE to detect cracks in refractory bricks and concrete. For these *in-situ* measurements, a metal tube waveguide coupled the AE signals to an external transducer. It seems that concrete is used increasingly as a refractory material, but it has problems in that it often cracks during the initial drying-out phase. W. Stengal (FRG) discussed the use of AE to study the progress of hydrogen embrittlement in metals. D. Miller (Imperial College, London) described his use of AE to study painted metal strips (automobile finishes) stressed to failure. His samples included new paints, some 5 years old, various methods of painting, and wet and dry conditions. R.W.B. Heng (University of Sheffield, UK) stressed several polymers (polyvinyl chloride and polypropylene) in an effort to study creep. His results were nil except at the point of rupture. This came as something of a surprise, and there were suggestions that the sensitivity of his equipment (a commercial system) was not adequate for the tasks. S. Hanagud (Georgia Institute of Technology) reported on his use of AE to characterize damage in woven carbon-epoxy composites as a function of moisture content. Water-saturated materials yielded high amplitude signals and high ring count. He concluded that one can use AE to determine moisture content accurately. His samples were tested in a tension machine. Moving to very large samples of materials, F. Baretick (Centro Informazioni Studi Esperienze SpA [CISE], Italy) discussed the use of AE to monitor the initiation of cracks in concrete structures. He first described laboratory experiments and then the use in a large concrete dam. G. Villa, also of CISE, described the program to develop an AE method to qualify very large high-pressure tanks. An example was a tank with walls 280-mm thick, tested to 288 bars. He presented a standard method for classifying AE signatures. Evidently, AE testing is to be one of the standard qualifications for high pressure tanks in Italy. This is not the case in most countries. A.M.H. Khafagy (Chelsea College), described a program to compare AE signatures and internal friction (as determined by ultrasonic attenuation) on samples of syntactic foam (glass spheres and epoxy) and metals, over a wide range of temperature. The acoustic signatures are in the 100- to 300-kHz range.

The examples cited above involved the use of naturally occurring or externally generated bulk stresses to generate AE signals. Several papers described the use of external acoustic sources to trigger AE. M. Arrington (AECL, UK) talked about the use of this arrangement for the inspection of composites. J.R. Webster (Rolls Royce, UK) presented a method using a Motorola tweeter loudspeaker to generate AE in a new type of gas turbine fan blades. These blades consist of two thick skins separated by a lightweight honeycomb core. The aim was to detect flaws and delaminations. T.J. Holroyd (Rolls Royce, UK) described what he called an

AE spin-off technique to perform the same function. In a well-made blade, the honeycomb space is a vacuum. If delamination occurs, air usually seeps in. He used a 150-kHz source and a conventional AE receiver. If the interior is a vacuum, the decay time of the received signal is on the order of 400 to 700 ms. If the void is air filled, the decay time is very short (20 to 200 ms) because of the attenuation of the signal in air. The technique involves the measurement of the decay slope. Measurements can be made while the blade is rotating (by using slip rings for electrical connections).

J. Mackersie (Robert Gordon's Institute of Technology, Aberdeen) reviewed a quite different form of AE. If a ferromagnetic material is subjected to magnetization, there is a discontinuous irreversible movement of domain walls; the result is an electromagnetic Barkhousen emission, which can be sensed as voltage pulses induced in a pickup coil during magnetization. More recently it has been observed that acoustic emissions are also generated, probably by the same process. However, the acoustic Barkhausen emission (ABE) has the advantage that changes deep within the material can be detected, while the electromagnetic effect (EBE) can be observed from a thin layer only. Both ABE and EBE are functions of the material microstructure and the stress.

Paul Cole (Dunegan Company, UK) described commercial equipment for AE and described some of the current and future uses for AE. The Halley's Comet space probe will carry an AE sensor. Judging by the papers at this meeting, Dunegan equipment is very popular in the AE community. Dunegan is a pioneer in this field, and his company (now separated from Endevco) probably is the major supplier of AE systems and transducers.

Voichita Bucur (Centre National de Recherches Forestières, France), presented a paper whose subject did not fit into either of the conference topics, but was quite interesting. She has computed the nine elastic constants of wood from her measurements of the speed of sound along the three natural axes of wood (to get the six diagonal terms) and at oblique angles (to get the nondiagonal terms). Her accuracy is about 3 to 4 percent on the axes and 4 to 20 percent at oblique angles. The aim is to relate the strength of timber to forestry practice such as pruning techniques. Better lumber through better acoustics!

Photo-Acoustic Spectroscopy (PAS)

The nine papers in the PAS portion of the conference related to photothermal processes, optical absorption, and thermal diffusivity. The only connection with acoustics is that for some of the experiments a microphone was used to detect a pulsating pressure (due to a pulsating temperature) in a test cell. No acoustic radiation or acoustic wave propagation was involved. In some of the experiments other devices were used to sense temperature, e.g., infrared (IR) detectors.

A typical PAS system consists of a light source (e.g., laser or xenon lamp with monochrometer) modulated by a mechanical light valve or chopper, a small cell containing the material to be analyzed, and a microphone. The modulated light strikes the sample, is partially reflected, partially absorbed, and partially transmitted. Absorption raises the temperature of the sample, which also raises the temperature of the gas filling the cell, which causes the pressure to increase. This increase in temperature is a function of optical frequency and intensity, the absorption coefficient of the sample, the thermal diffusion coefficient, and the modulation frequency. Optical frequencies include ultraviolet, visible, and IR. Modulation frequencies range from 10 to 1000 Hz but generally are from 10 to 200 Hz. A high modulation frequency is used to study absorption and diffusion near the surface, while lower frequencies are used to investigate deeper layers. The microphone amplifier is locked to the modulation frequency. Usually it is necessary to measure both the amplitude and phase of the sensed signal. Generally measurements are made over a band of optical frequencies. To measure deep within a sample, one measurement is made with a high chop frequency, and this is subtracted from measurements made at a low chop frequency to yield data for a layer within the sample. The usual output data are optical absorption and thermal diffusivity as a function of optical frequency.

B. Girault (Université des Sciences et Techniques du Languedoc, France) presented a paper on the use of PAS to study thermal diffusity and optical absorption coefficients in semiconductors. He employed chop frequencies from 10 to 1000 Hz. L.P. Vickery (Manchester University, UK) described his work on using PAS to study leaves. His system used a pseudo-random modulation, which allowed a much faster analysis. D.M. Patel (University of Bath, UK) used PAS to detect defects in plasma-sprayed coatings and to measure coating thickness. He used a laser source and IR detector. M.T. Liezers (Manchester University, UK) used a similar technique

to investigate spray metal coatings and thin polymer films. He used an IR detector and a chop frequency from 200 to 500 Hz. A.B. Rejab (Chelsea College), used PA techniques to examine several types of fibrous materials, which were being considered for use as substitutes for asbestos mats.

G. Busse (FBET, Munich) showed results of a thermal imaging system which involved thermal transmission through the sample (which contained anomalies). The light incident on the front surface of the sample was modulated. The heat generated by absorption diffused through the sample in bundles. The speed of diffusion could then be calculated. For one sample it was about 12 cm/s. Busse refers to this as a "thermal wave," but it is not a wave in the usual sense. However, the thermal pulses are reflected at thermal discontinuities. He employed chop frequencies of 18 and 180 Hz.

D.H. McQueen (Chalmers University, Sweden) gave an excellent paper on his development of a new technique, using a PA cell, to measure the hemoglobin content of blood. A single drop of blood is put on a sapphire wafer in the cell. The incident light (a single frequency, selected to be at the peak for hemoglobin absorption), chopped at 32 Hz, passes through the blood, being partially absorbed, and then to the sapphire where it is absorbed and generates an acoustic signal, which is detected by a piezoelectric microphone. The calibration curve of absorption versus hemoglobin content was very linear and repeatable (within 1.0 percent). The results are within 1 percent of measurements made using much more expensive equipment and requiring more time and a larger sample. The McQueen device requires only 10 seconds for an analysis. He said that blood analysis was a very popular procedure in Sweden--for a total population of 8 million there are 1.2 million hemoglobin analyses each year. He feels that the general technique can be applied to other types of blood analysis but not necessarily to other liquids. He pointed out that blood is a unique fluid in that it is very uniform; that is, blood samples from healthy bodies are very similar, and those from sick bodies are distinctly different but also very uniform in the difference.

T.H. Ryan (EDT Research, London) described the PAS equipment that his company manufactures and markets. About 30 PA spectrometers have been sold worldwide. He summarized some of the work done by the users.

Status of AE Research

The Chelsea conference had several interesting and probably important papers. It was not as large as some previous ones on the same subjects. In part this may have been due to the timing--the week just before Christmas may not have been convenient for some who work in the field. I am not qualified to attribute the small size to a lack of interest.

AE has had time to mature. I understand that there are now some 3000 literature references on the subject. It is noted that AE and PAS are both NDT techniques, and many papers which would have been appropriate for Chelsea may have been given (or will be given) at special NDT meetings. The *Journal of Acoustic Emission*, published by the University of California at Los Angeles, was started in 1982. The editor is Prof. Kanji Ona, with an editoral board composed of people from the US and Japan. Recently a European editor and board have been established (Dr. Robert Hill, Associate Editor, and a board of 14 others). The 7th International Acoustic Emission Symposium will be held in Sendai, Japan, from 23 through 26 October 1984.

These points indicate that AE is an active field. One attendant told me that there was an AE boom in the sixties and seventies and that the technique may have been oversold, that some people expected it to do all things. I have the impression that the bulk of work has been on NDT applications and that there is room for a great deal of basic research, which in turn likely will lead to improved or new applications.

1/23/84

OPERATION OF A STORAGE RING FEL

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A French-American collaboration working at the University of Paris-Sud in Orsay has reported the first successful operation of a free electron laser (FEL) in a storage ring. With an output wavelength in the red-orange, the

experiment is also the first to operate in the visible regime. The achievement is a result of a 3-year cooperation between the university's Laboratory for the Utilization of Electromagnetic Radiation (LURE) and the High Energy Physics Laboratory (HEPL) of Stanford University--the first group to demonstrate successful FEL operation with a linear accelerator.

Background

Of the many types of lasers currently under investigation, the FEL is the only one not requiring a lasing medium supporting a few lines of precise wavelength or narrow tunability. Applications for conventional lasers depend on matching these narrow portions of the electromagnetic spectrum to targets and processes. The FEL is not tied to an atomic- or molecular-level structure, and its primary attraction is continuous tunability over a wide wavelength band. Tunability in an FEL is provided by changing the electron energy and the amplitude or wavelength of a periodic magnetic field structure (called an undulator or, less precisely, a "wiggler" magnet) that causes the electron orbits to oscillate. The oscillating electrons emit dipole radiation, which interferes constructively at the output wavelength of the laser. The output wavelength is given by

$$\lambda = \lambda_w(1+K^2/2)/2\gamma^2. \qquad (1)$$

In equation (1), λ and λ_w are the output and wiggler wavelengths, γ is the electron relativistic factor, $K \sim \lambda_w B$ measures the angular deviation of an electron from the magnet axis and is in the range of 1 to 3.

Reducing the undulator wavelength or increasing the electron energy tunes the FEL to shorter output wavelength. In theory, an FEL can be tuned into the x-ray regime using highly relativistic beams and short-period field structures. In practice, technical problems related to optical-cavity losses, field inhomogeneities, beam alignment, brightness, and energy spread limit current research to the visible and infrared (IR) regime.

High-power FELs operating in the visible and IR have important research and commercial applications. By tuning to particular electronic and molecular excitations, and exploiting the spectral purity and time structure of the radiation, chemical and solid-state changes in matter not otherwise possible can be induced. Industrial applications are found in areas as diverse as electro-optics and pharmacology.

High average power FELs will be required for economic rates of material processing. The possibility of high power at high electrical efficiency is a second important advantage of FELs over conventional lasers. Several tens of percent seem reasonable for properly designed systems (Sprangle, 1979). High efficiency makes the FEL an attractive alternative driver to lasers and particle beams for inertial confinement fusion. Currently, only CO_2 gas lasers operating in the IR are efficient enough to be cost effective in commercial applications (*ESN* 36-11:303 [1982]). These operate at order-of-magnitude lower efficiencies than envisioned for FELs.

High power FEL operation at short wavelengths for missile defense is the objective for a large fraction of the US research effort sponsored through the Defense Advanced Research Projects Agency. The US Navy supports the design of low electron energy FELs in the visible through microwave regimes for defense, submarine communications, and materials research.

Each of the three possible types of electron beam sources is represented in European FEL research. Microwave FEL operation using megaelectronvolt beams extracted from pulse-line generators is under study at the École Polytechnique, Palaiseau, France (Vallier, 1983). This type of laser has been successfully operated by researchers at the Naval Research Laboratory, Washington, DC (Granatstein, 1983).

Visible and IR FEL devices use electron beams extracted from conventional accelerators. Undulators are mounted either in a linear accelerator (linac) beam line or in the circulating beam path of a storage ring. For oscillator operation, the undulator is placed within an optical cavity, and the radio-frequency (rf) time structure of the electron beam is synchronized with the transit of photons between the two reflecting surfaces of the cavity.

A major new linac FEL project has received approval by the UK's Science and Engineering Research Council (SERC). The project, a collaboration between the Kelvin Laboratory of the University of Glasgow, Heriot-Watt University in Edinburgh, and the Daresbury Laboratory in Warrington, hopes to demonstrate high gain and power tunability over the 2.0- to 20-μm region of the IR spectrum (*ESN* 37-10/11:419-422 [1983]). A .20-MeV, several-ampere microtron beam is used to study linac FEL operation in the 25- to 35-μm range at the Comitato Nazionale Energia Nucleare laboratory in Frascati,

Italy (Dattoli et al., 1981). The Stanford linac operating at 24 MeV was the first FEL experiment to demonstrate gain (Elias et al., 1976). In a follow-up oscillator experiment at 43 MeV, 7-kW power output at 3.4 μm was observed.

There are three FEL experiments currently mounted on European storage rings. Besides the ACO ring in Orsay, there are optical frequency experiments in progress on the VEPP3 storage ring in Novosibirsk, USSR, and on the ADONE storage ring at Istituto Nazionale di Fisica Nucleare in Frascati, Italy.

Storage rings have several advantages over linear accelerators for some FEL applications. Since the beam is recirculated, only the few-percent energy loss of the beam at each pass through the undulator need be replaced. In a linac, each beam bunch makes a single pass before the beam is dumped (absorbed in a solid target). Thus, storage rings have the capacity for much higher conversion efficiencies of electricity to light--an important economy for large-scale industrial applications. Operation in the visible or ultraviolet requires high beam energies and small field structures--see equation (1). Storage rings are superior to linear accelerators for high energy operation and can achieve higher current density and beam quality. However, their large size precludes the use of conventional storage ring FELs in many defense applications. I spoke with Pascal Ellaume of LURE about the French-US collaboration that resulted in first operation of a storage ring FEL. Other members of the research team include M. Billardon, J.M. Ortega, C. Bazin, M. Bergher, M. Velghe, and Y. Petroff from LURE, D.A.G. Deacon, K.E. Robinson and J.M.J. Madey from HEPL.

The LURE Experiments

The measurements from Orsay have demonstrated three important firsts for the free electron laser: visible-light output, operation with a recirculating beam, and use of an optical klystron configuration in the magnet structure. The experiments were carried out on ACO, a 22-m circumference storage ring. A major limitation of the device is the small size that limits the undulator length to a straight section of 1.3 m. Since the FEL gain scales like the cube of the wiggler length, successful operation at Orsay is a formidable task when compared with other experiments. Both the Stanford and UK experiments employ 5-m wiggler lengths with theoretical gains above 10 percent per pass. The best gain achievable on ACO is two orders of magnitude lower. Thus, a successful experiment in Orsay bodes well for others in preparation with intrinsically higher gains.

FEL lasing in an oscillator can be achieved when light amplification in the undulator exceeds end losses at reflection: For ACO, with gains per pass measured in hundredths of 1 percent, the end mirrors must be nearly perfect reflectors at the output wavelength. The dielectric mirrors used on ACO consist of 24 alternating layers of TiO_2 and SiO_2, each a quarter-wave thick. At 630 nm, new mirrors have an astounding 99.992 percent reflectivity.

Oscillator experiments were first attempted about 2 years ago using a permanent magnet undulator of 17 periods optimized for 240-MeV electrons. At that energy, the mirrors were degraded over a period of hours by ultraviolet (UV) spontaneous emission within the undulator. With degraded mirrors, losses exceeded the minuscule gain, and laser oscillation was impossible. Successful operation was achieved last summer because of two main improvements to the experiment: increasing the gain by modifying the undulator, and reducing UV damage by lowering the beam energy (Billardon et al., 1983).

Gain enhancement by a factor of 2 to 7 has been achieved by going to an optical klystron configuration (Elleaume, 1982), a modification invented by A.N. Skrinsky and N.A. Vinokurov of the Institute of Nuclear Physics in Novosibirsk. The central three periods of magnet blocks were replaced with others to produce a single period of larger amplitude. This section strongly enhances the bunching originating from the electron-radiation interaction in the first undulator section to give a larger energy transfer to light in the second undulator section.

The UV mirror degradation was reduced by lowering the electron energy to the minimum value at which FEL oscillation was possible: 160 to 166 MeV. The undulator magnetic field strength was reduced by increasing the magnet gap (see equation 1) so that the output wavelength remained in the 650-nm regime.

Laser oscillation was achieved following 0.1-mm alignment of the electron beam with the axis of the klystron and synchronization of the storage ring rf voltage with light transit across the optical cavity. Precise synchronism between reflecting light pulses and the revolution frequency of electron bunches is crucial to FEL operation. To avoid mechanical problems associated with mirror

displacement of a few microns, this tuning was accomplished by fine adjustment of the rf in steps of 1 Hz. The optical cavity characteristics for the oscillator experiments were: length of 5.5 m, end mirror radius of curvature of 3 m, wavelength range for maximum Q of 620 to 680 nm, average round-trip cavity losses of 7×10^{-4}, and mirror transmission of 3×10^{-5}. Laser oscillation lasted about 1 hour, the circulating beam lifetime.

Figure 1 shows two spectra of light output. Curve a is recorded with the optical cavity completely detuned, while curve b shows lasing in three lines with a tuned cavity. The line at 647.6 nm is strongly dominant, and typical full widths at half maximum are 0.2 to 0.4 nm. By changing the magnet gap, the FEL could be tuned between 640 and 655 nm with the tunable range limited by mirror reflectivity.

Figure 2 presents horizontal and vertical transverve profiles of the laser output intensity. The figure shows the beam to be cylindrically symmetric with a profile close to that calculated for the TEM_{00} cavity mode expected to be dominant. Discrepancies with theory are attributed to laser instability at low gain or nonuniform mirror reflectivity.

A typical 75-μW average output power was reported at a 50-mA current of 166-MeV electrons. This corresponds to a 60-mW peak output power over a 1-ns electron bunch length and a 2-kW intracavity peak power. The 75-μW figure was about half of what one would calculate from the observed mirror efficiency and electron energy spread (Renieri, 1979). Space charge effects which increased the bunch length and energy spread prevented an increase in gain with higher beam current.

Lasing is achieved in sub-nanosecond bursts corresponding to maximum density in the 1- to 2-ns electron bunch. Since two bunches circulate in the ring, the bursts are spaced by about 40 ns. However, much of the interesting physics is associated with more subtle phenomena occurring on longer time scales. A 13-kHz modulation of the bursts is due to electrostatic oscillations at the synchrotron frequency of the electron cloud. Most interesting is the longer period, macro-time behavior of <P>, the power averaged over the fast-time scale. The quantity <P> rises with the 200-μs growth rate expected from the measured gain and cavity transit time. Following the rise, rather than saturating, <P> drops back to a low level for 5 to 20 ms and then

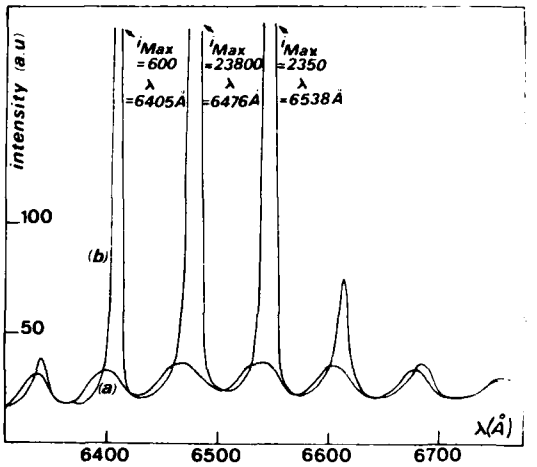

Figure 1. Spectra with (a) detuned and (b) tuned optical cavity.

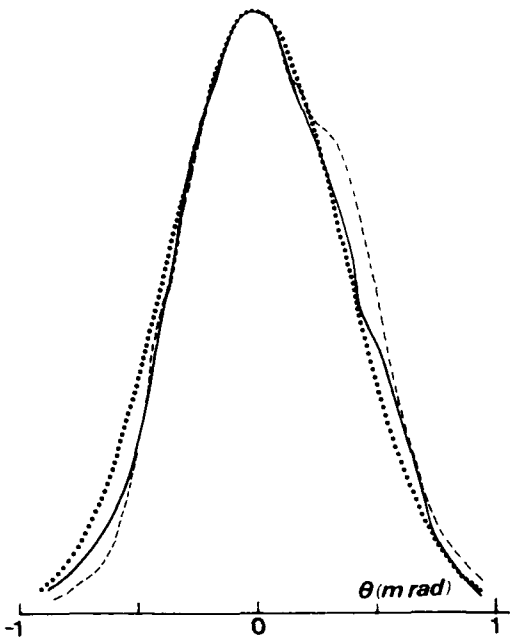

Figure 2. Experimental horizontal (solid), vertical (dashed), and theoretical (dotted) profiles.

rises again. First reports of lasing (Billardon et al., 1983) offered no theoretical explanation.

In January 1984, I visited Pascal Elleaume of LURE to learn of new theoretical and experimental results. He described a nonlinear model to account for the macro-structure, important new data on mirror performance, and improved laser operation arising from that data.

The temporal model is based on a pair of coupled nonlinear equations for I and Σ, dimensionless measures of micro-time-averaged pulse energy and energy spread.

$$\frac{dI}{dt} = (1-\Sigma)I/\tau_o$$

$$\frac{d\Sigma}{dt} = 2(I-\Sigma)/\tau_s \qquad (2)$$

In equations (2), τ_o is the laser rise time due to gain less end losses, and τ_s measures energy-spread decay due to synchrotron radiation. Elleaume solved the equations by linearizing about the stationary solution I = Σ = 1. The equilibrium is stable but oscillates with a period

$$T = 2\pi\sqrt{\tau_s\tau_o/2} \quad . \qquad (3)$$

For the Orsay experiment, $\tau_s \simeq 200$ ms and $\tau_o \simeq 0.05$ ms so that $T \simeq 14$ ms. This is the correct time scale for the macrostructure, but numerical solutions of the nonlinear equations must be performed to predict laser pulse shapes. One interesting point arising from the linear analysis is that higher peak powers are predicted when the laser gain is modulated by periodically misaligning the beam, detuning the rf, or varying the cavity length with a piezoelectric device.

The new mirror data derive from two techniques for measuring high reflectivity and are described in a LURE internal report entitled "Mesures vers 650 nm de la Degradation de Reflectivite de Miroirs Multicouhes Dielectrique de Tres Haute Reflectivite Utilises pour le Laser a Electrons Libres d'Orsay." Figure 3 illustrates the results. A new mirror (a) shows 99.99 percent reflectivity over nearly 1000 angstroms. Ultraviolet synchrotron radiation causes damage that reduces the performance by an order of magnitude in a few minutes (b). An additional 40 hours of irradiation produce further degradation, except in the vicinity of 6700 angstroms (c). Ellaume explained this behavior by suggesting that curve (b) was due to bulk damage while curve (c) was produced by long-term surface degradation. For the dielectric mirrors, the electromagnetic field has a node at the surface near 6700 angstroms so that reflectivity is determined by the underlying bulk damage. With FEL operation at this wavelength, even old mirrors can be used for many hours. The vertical line

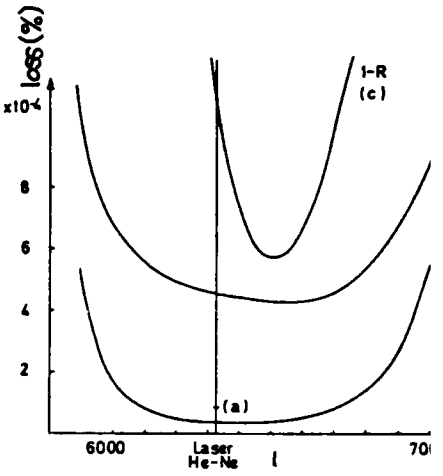

Figure 3. Mirror reflectivit
wavelength.

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operating wavelength in earl
ments and the reason why lasin
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Figure 3 and a simple retunin
at 6700 angstroms might h
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With the shift of the
point to the 6700-angstrom
the latest experiments, laser
ance can be improved. The sto
is now operated at 225 MV be
associated higher synchrotron
can be tolerated by the mir
this electron energy, abou
average power has beam measured
electron current.

Future Plans

Although the recent
achievements of the Orsay-Stan
laboration have been impressi
limitations continue to pre
development of a high-gain FE
Short-term plans include mo
streak camera to determine t
time structure of the laser
investigation of nonlinear
generation in the UV by inter
the FEL with a glass laser. A
improvements in performance are
with the storage of positron
than electrons in the ring--t
interact as strongly with b
ions in the vacuum chamber
tighter beams with higher
expected. With positrons,
there is a new technical
collecting and storing enough c
achieve lasing.

In the long term, the group hopes to mount a 5-m undulator on the larger, 2-GeV DCI ring at Orsay. On such a device, gain in the UV will be high enough to overcome large mirror losses and operation down to about 2000 angstroms may be possible.

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1/24/84

PROGRESS IN PLASMA PUFF RESEARCH IN FRANCE

by David Mosher.

Intense, soft x-ray sources produced from the magnetically driven implosion of annular plasmas are the subjects of active research around the world (*ESN* 37-3:115 [1983], 37-9:373 [1983], and 38-2:93 [1984]). These plasma sources of kilovolt lines and sub-kilovolt continuum are useful in basic spectroscopy and condensed-matter research, microlithography, x-ray laser development, and defense-related nuclear vulnerability studies. It has been proposed to use such a source as a driver for inertial confinement fusion targets. The sources are intense and efficient enough for large-scale commercial processes, and when driven by state-of-the-art pulsed-power systems, they are the highest energy sources available in the kilovolt-and-below regime. Yet all important physical processes and some applications can be studied with readily available capacitive storage systems in modest university laboratories.

For all of this research, a cylindrical shell of gas or plasma is created in the few-centimeter gap separating the electrodes of a high-current pulse generator. A variety of elements can be researched either by injecting a supersonic gas puff with an annular nozzle or by exploding an annular array of fine wires. When the driver is discharged through this load, large current flow in the annulus produces magnetic forces which radially implode it to a high energy density z-pinch plasma of much smaller radial dimensions. As the plasma stagnates about the axis of symmetry, the kinetic energy of implosion is converted to internal energy and radiation. There are two important requirements for the annulus before implosion: the mass must be correct to fully implode just after current maximum, and the gas or plasma all must be contained within the annulus--the appearance of matter on axis before implosion limits the radial compression, and its presence within the vacuum electrical feed to the diode can short out the discharge.

About a year ago, I reported on a new technique to produce hollow plasma annuli that appears to have several advantages over supersonic puff-gas and exploded-wire sources (*ESN* 37-3:115-118 [1983]). The so-called "plasma-puff" system, based on the fast electrical explosion of 5-μm-thick aluminum foil, was developed by Prof. Henri Doucet and a research team consisting of B. Etlicher, J.P. Furtlehner, M. Gazais, H. Lamain, and C. Rouille at the École Polytechnique in Palaiseau, France. At the time of my first visit, the creation of a well-collimated and axi-symmetric aluminum vapor annulus was demonstrated. However, there were no firm measurements of plasma-puff density or velocity, and GAEL--the 500-kV, 250-kA implosion driver--had not yet been discharged through the plasma load. On a return visit to Palaiseau during January 1984, I learned of recent progress in the experiment. A powerful interferometry technique has been employed to measure the atomic density and the velocity of the plasma as it fills the diode, and GAEL has been discharged through the load. These first implosion experiments have led to a recent redesign of the cathode to eliminate plasma shorting of the diode. Following a brief review of the experimental set-up, recent progress is discussed in this article.

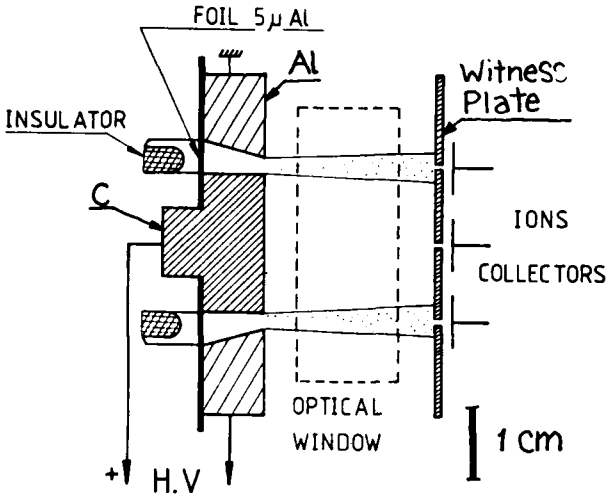

Figure 1. The plasma puff assembly.

A diagram of the plasma puff assembly used in experiments previous to coupling with GAEL is shown in Figure 1. The expanding, vaporized foil is collimated by the aluminum cone and graphite cylinder shown to form an annulus in the vacuum gap viewed through the optical window. The radial thickness of the shell increases from 2 to 4 mm as the jet passes from left to right in the figure. The capacitive discharge source used to explode the foil was described in the earlier report but has been raised in voltage from 15 to 25 kV since that time.

A year ago, preliminary "guesstimates" of plasma mass and density were made by weighing the mass which built up on the witness plate after a number of shots. The plasma velocity and pulse length were estimated by measuring the current through biased charge collectors as a function of time. The charge collector measurements were erratic because their proximity to the foil (3 cm) resulted in plasma shorting.

Much more accurate measurements of plasma density and axial-flow velocity are needed to accurately match the load dynamics and generator electrical characteristics. To this end, Doucet and coworkers have performed measurements using a resonance-line interferometry technique (Koopman et al., 1977). Conventional laser interferometry relies on a fringe-shift pattern produced by plasma electrons in the laser path. The technique has been used successfully by many researchers to study the developed implosion phase of annular plasmas and other dense plasmas. However, the electron density in gas and plasma puffs is too low during the initial annulus-formation phase to produce a measurable fringe shift--the atomic density is low, and the cool plasma is only slightly ionized. Neutral pressure measurements (such as with fast ionization gauses or piezoelectric detectors) cannot give detailed density distributions. The resonance technique is about two orders of magnitude higher in sensitivity than conventional interferometry and relies on refraction produced by neutral atoms rather that electrons.

In the vicinity of the neutral aluminum resonance line at 3944.01 angstroms, the index of refraction n varies rapidly according to:

$$n = 1 + 1.58\times10^{-20}\ N_o/\Delta\lambda, \qquad (1)$$

where N_o is the atomic density in cm^{-3} and $\Delta\lambda$ measures the difference between the laser light and resonance wavelengths in angstroms. (Doucet et al. discuss this in a paper submitted to the *Journal of Applied Physics*.) At the resonance wavelength, the free electron contribution to n is given by

$$n = 1 + 6.98\times10^{-23}\ N_e, \qquad (2)$$

where N_e is the electron density. For $\Delta\lambda$ of order 1 angstrom and $N_o = N_e$, the resonance technique is seen to be several hundred times more sensitive than conventional interferometry. With $\Delta\lambda$ = 0.5 angstrom, a neutral line density of about 1×10^{15} cm^{-2} is sufficient to produce a one-fringe shift. This sensitivity is adequate for the lowest mass imploded-plasma loads of interest to x-ray source development.

In the experiment, a dye laser driven by a 500-kW, 5-ns nitrogen laser is tuned to within about 1 angstrom of the aluminum resonance. An adjustable delay generator triggers the dye laser to obtain interferograms at different times in the plasma flow. As a check that the observed fringe patterns are due to the resonance refraction, the dye laser was tuned through resonance and, as required by equation (1), the direction of light bending was observed to change as n-1 changed sign. In interferograms with $\Delta\lambda$ = 0.5 angstrom taken about 3 μs after foil explosion, the leading edge of the plasma jet ($N_o \simeq 10^{15}$ cm^{-3}) can be observed, and a front velocity of about 0.5 cm/μs can be estimated. At 6 μs, the plasma annulus fills the field of view, and $\Delta\lambda$ = 2 angstrom measurements result in a mean density of about 1×10^{16} cm^{-3} over a 2-mm width. Although the optical depth can

be measured accurately from the fringe-shift pattern, the measurements are uncertain by about 50 percent because the density profile across the annulus is unknown.

The fastest aluminum atoms observed have a kinetic energy of about 10 eV. The total electrical dissipation in the foil is about 50 J (much less than the energy stored in the capacitors because of rapidly changing foil resistance and parasitic circuit inductance), which corresponds to 7.5 eV per atom. Since about 17 J are required to vaporize the foil, the observed kinetic energy for the fastest particle seems reasonable.

Many more measurements will be required to properly characterize the plasma puff. Still, these first interferometry results demonstrate the ability to determine the mass of the annulus and the time dependence of axial and azimuthal mass distributions--important measures of the potential implosion quality and x-radiation emission. The technique has a drawback: the over $10,000 price tag of the dye laser system can put a crimp in the budget of a small laboratory.

At the end of 1983, the GAEL pulsed-power generator was coupled to the annular load by replacing the cathode witness plate and ion detectors with a hollow cylindrical cathode snout. The central hole to the interior was about the same diameter as the plasma annulus. The idea was to "dump" and condense the plasma puff inside the cathode so that the vacuum space separating the snout from the return current wall would not be contaminated with gas or plasma. The precaution was not completely successful. The first implosion experiments were marked by frequent shorting of the vacuum feed during the electrical pulse. The breakdown time varied from shot to shot so that visible-light streak camera photographs showed erratic implosion characteristics.

Doucet believes the shorting medium may not be aluminum vapor but lower-atomic-number impurities from pump-oil and outgassing. The charge collector experiments support this view. The detector current shows several peaks corresponding to different atomic species. The first peak is probably due to protons or hydrocarbon ions. These impurity species may not be as tightly collimated in the annulus as the aluminum, are not condensed, and therefore may be filling the vacuum feed. Doucet has now enlarged the hole in the cathode to trap more impurities within and has angled the perimeter of the hole to reflect colliding atoms into the dump space. With such improvements and the interferometry results, he hopes to demonstrate precise control of the plasma implosions by varying the timing of foil explosion relative to the GAEL pulse. Success will demonstrate the utility of a novel, and perhaps superior, technique to create annular plasmas for intense soft x-ray sources.

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1/25/84

SCIENCE POLICY

UK 1984 SCIENCE BUDGET

by James W. Daniel, Scientific Director for Europe and the Middle East for the Office of Naval Research's London Branch Office. Dr. Daniel is on leave until September 1985 from the University of Texas, where he is Professor of Mathematics, of Computer Sciences, and of Education.

Government support of basic science in the UK will grow by about 6 percent for 1984 over that for 1983, an increase in both cash and real terms. Yet serious problems caused by international science commitments and by the need for internal restructuring of the support of science have left scientists disappointed; it's a case of more meaning less.

Background

Almost all the support of basic scientific research in the UK is funded through the five Research Councils, about five-sixths of whose funds are received from the government's Department of Education and Science in the so-called "Science Budget." An earlier article (*ESN* 38-2:104-107 [1984]) described this system and the funds recommended for the Councils by the influential Advisory Board for the Research Councils (ABRC) in the Forward Look it published in October 1982; that article provides useful background for this one.

The government of Prime Minister Thatcher has promised to support science at a nearly constant level in real

Table 1

Funding for Research Councils

	Forward Look Recommendations for 1984	Actual Allocations for 1984
AFRC	£ 70,350,000 (8.8%)	£ 69,750,000 (8.8%)
ESRC	£ 36,750,000 (4.6%)	£ 33,000,000 (4.1%)
MRC	£178,650,000 (22.4%)	£178,500,000 (22.4%)
NERC	£ 91,800,000 (11.5%)	£ 97,500,000 (12.3%)
SERC	£397,200,000 (49.8%)	£417,000,000 (52.4%)*

* About £9,000,000 of this is a special supplemental allocation--although £15,000,000 was urgently requested--to help SERC with the financial drain caused by its membership in the multinational European Organization for Nuclear Research (CERN) and the European Space Agency (ESA).

terms, despite the loss in real value of support for most other government activities; this promise has been kept. The ABRC's Forward Look in 1982 called for about £803,000,000 in the 1984 Science Budget in order to maintain this level funding; in March 1983 the government increased the planning figure to about £814,000,000 in order to account for inflation. The actual total being allocated for 1984 is about £823,000,000, compared with 1983's £776,000,000. Although this represents a small increase in real terms, it remains some £52,000,000 below the amount the ABRC claimed in March 1983 would be necessary for "the continuation and development of existing policies." You have to look more closely at the individual Research Councils and their operations in order to understand why UK science seems worse off this year than last, despite its increased budget.

The Research Councils

My February article sketched the five Research Councils: Agricultural and Food (AFRC), Economic and Social (ESRC), Medical (MRC), Natural Environment (NERC), and Science and Engineering (SERC). In proposing funding levels for 1983 through 1985, the ABRC recommended in its Forward Look that only the AFRC receive a decreasing share of the total allocation to the Research Councils (from 9.2 percent down to 8.5 percent), and that only the SERC receive an increasing share (from 49.3 percent up to 50.2 percent), with the others' shares staying essentially constant. The Forward Look recommendations for 1984 are shown in Table 1, along with the actual allocations announced by Sir Keith Joseph, Secretary of State for Education and Science. In broad outline, the actual allocations are like those proposed. The cut in the allocation for the ESRC appears to reflect Sir Keith's doubts about the value of the social sciences, while the boost for the NERC continues 1983's increased research in the Antarctic growing from the Falkland's conflict.

The above figures conceal the real problems. Both the AFRC and the NERC are being compelled by the government--as recommended by the ABRC--to shift their emphasis from supporting research largely in their own institutes and research establishments to supporting research primarily at universities. This means that monies must be diverted from research support to providing pensions for those "retiring early" at the AFRC and NERC establishments being cut back or closed; the AFRC, for example, estimates that this restructuring will cost some £7,500,000 in 1984 and twice that in 1985. The AFRC has announced plans to close its Letcombe Laboratory and the Weed Research Organization, a loss of 250 jobs by this spring; jobs are being eliminated at other AFRC establishments as well. And the situation for the NERC is similar. Thus these two Research Councils not only are struggling to eliminate jobs and reorganize their support of science, but also are having to divert funds from research support to the support of terminated employees. The ABRC has recommended that the MRC and the SERC budgets during 1985-87 be reduced by 0.75 percent and 1.5 percent respectively in order to obtain funds to assist the NERC and the AFRC restructuring.

The forces causing SERC's problems are different, although SERC too is examining the possibility of reducing the central facilities it maintains (the

Royal Greenwich Observatory, for example, narrowly avoided closure). The fall in the value of the pound sterling and the rise in the UK gross national product relative to those of other European nations mean that the UK subscriptions to CERN and ESA are increasing; this problem has continued for several years and is expected to cost the SERC an extra $15,000,000 in 1984 compared with 1983. The $9,000,000 special allocation in the Science Budget and a recent $1,500,000 added to it to assist with the international subscriptions still leave the SERC having to find an extra $4,500,000 in its 1984 budget; the money will have to come from other research projects. In addition, costs of the "big science" supported by the SERC appear to be increasing much faster than inflation, thus putting further pressure on the budget. And finally, the financial problems of universities--where most SERC money is spent--prevent them from providing basic laboratory research equipment and require the SERC to expend more of its funds for such items. (For more detail on the SERC, see the next article.) Supporters of the SERC also fear that in the near future funds will--as recommended by the ABRC--be diverted from the SERC to assist the AFRC and NERC with their severe pains of restructuring.

Conclusion

UK science has a distinguished history, with more Nobel prize winners per capita than in any other country. The government and the scientific community appear committed to maintaining this record and to holding level or increasing the support for science despite the government's financial problems. Part of this effort involves shifting support from government establishments to universities, where it is believed the best research is conducted; another part is to participate in multinational scientific projects in order to hold down the UK's individual commitments to big science. Yet these last two efforts also create new pressures on the limited funds available for science. What the ultimate result will be is not clear.

1/19/84

SCIENCE AND ENGINEERING RESEARCH COUNCIL STRENGTHENS UK RESEARCH CAPABILITY

by James W. Daniel.

The Science and Engineering Research Council (SERC) is the UK government's primary agency for improving the country's capability for pure and applied research in astronomy, geophysics, the biological sciences, chemistry, engineering, mathematics, and physics. The SERC concentrates on direct research awards to individuals and university departments, but it also supports postgraduate training and provides central facilities nationally and internationally.

Background

The Department of Education and Science provides through the so-called "Science Budget" over 96 percent of the SERC's funds, as well as funds for the other four Research Councils. The system of Research Councils is described in *ESN* 38-2:104-107 (1984), including information on trends and plans; the article beginning on page 213 of this issue reports on the 1984 Science Budget and its impact on the Research Councils. In this article, therefore, I concentrate on the structure, operation, and programs of the SERC.

Structure

The Council itself comprises about two dozen distinguished scientists and engineers, with a professional support staff of some 400 to manage the diverse programs operated under its $417,000,000 1984 budget; the chairman is Prof. John F.C. Kingman, FRS. Roughly 90 percent of SERC funds are controlled by its four Boards, with the remainder going for administration and centrally supported activities.

Astronomy, Space, and Radio Board. Chaired by Prof. K.A. Pounds, FRS, this Board supports a wide range of research, including atmospheric science, climatology, astronomy, and astrophysics. It typically expends 15 to 20 percent of the SERC budget, distributed in 1983 as 17 percent on research grants, 3 percent on postgraduate awards, 57 percent on central facilities, and 23 percent on international contributions. The central facilities funds go to the Royal Greenwich Observatory at Herstmonceux and the Royal Observatory at Edinburgh; international participation includes the European Space Agency, the Infrared Astronomical Satellite, the UK Infrared Telescope, and the Anglo-Australian Telescope. A recent trend toward decreasing shares of the total SERC budget has caused the Board to eliminate some programs, such as the small rocket and balloon facilities; a study panel is considering the possibility of closing the Royal Greenwich Observatory as a further economy measure.

Engineering Board. This Board has been receiving an increasing share of

the SERC budget: 15 percent in 1979, 23 percent in 1983, and a planned 29 percent by 1987. Chaired by D. Downs, CBE F Eng, it distributed its 1983 funds as follows: 64 percent on research grants, 23 percent on postgraduate awards, and 13 percent on central facilities. Its primary growth area has been information technology, although microelectronics has also expanded significantly. Several programs seek to stimulate technology transfer and university-industry interaction: fellowships for industrial researchers to develop academic courses, student scholarships for work on industrial problems, awards for continuing technical education for industrial technologists, and the Teaching Company scheme to bring universities and industries closer together by placing graduates in industrial positions to carry out a university-industry project. Areas of special interest to the Board include information technology, microelectronics, man-machine interfaces, image processing, process engineering, robotics, polymer and other material science, energy, marine technology, and so on.

Nuclear Physics Board. Earlier large reductions in the support of "big science"--from 31 percent of the SERC budget in 1979 to 22 percent in 1983--reflected the completion of some large development projects, but the Board's share has now nearly stabilized at around 20 percent. Chaired by Prof. Ian Butterworth, FRS, the Board distributed its funds in 1983 as follows: 12 percent in research, 2 percent in postgraduate awards, 34 percent in central facilities, and 52 percent in international contributions. The latter two large shares both go to provide expensive experimental facilities and severely hamper the Board's ability to provide research grants and postgraduate awards. The important domestic facilities include the nuclear structure facility's Van de Graaff accelerator at the Daresbury Laboratory in Warrington and the neutron source at the Rutherford and Appleton Laboratories in Chilton. The international support goes to the famous facility of the Organization for European Nuclear Research (CERN) in Switzerland; the fall in value of the pound sterling and the rise in the UK gross national product relative to those of other European nations have caused the pound commitment to CERN to increase rapidly in recent years (see the preceding article). How to maintain its CERN support without crippling all its other programs is the primary challenge facing the Board.

Science Board. Prof. J.I.C. Cadogan, FRS, chairs the Board responsible for the core of UK research in fundamental aspects of biology, chemistry, mathematics, and physics. Its share of the SERC budget has remained fairly stable at around 26 to 28 percent, with the 1983 funds distributed as follows: 31 percent for research grants, 29 percent for postgraduate awards, 31 percent for central facilities, and 9 percent for international contributions. As with the Engineering Board, this emphasis on research grants and postgraduate awards reflects a concentration on the individual research worker or small research group; the support of the Synchrotron Radiation Source at the Daresbury Laboratory and the Central Laser Facility at the Rutherford and Appleton Laboratories, which claims a significant portion of Board resources, is considered necessary in order to provide costly equipment for use by university researchers throughout the nation. The Board is now in the midst of a major strategy shift. Instead of only supporting the best science and scientists regardless of field, the Board is now identifying broad research themes--such as the rational design of biologically active molecules--cutting across standard disciplines; funds will then be distributed by committees overseeing each theme. The Board hopes that this will produce more results in areas ripe for breakthroughs than has its previous strategy.

Programs

SERC programs fall into four main areas: research grants, student support, central facilities, and international subscriptions. In 1983 the SERC divided its budget among these areas as follows: 29 percent, 15 percent, 38 percent, and 18 percent, respectively. Plans for the future call for a greater emphasis on the first two areas: 32 percent, 18 percent, 33 percent, and 17 percent, respectively. The central facilities and international subscriptions have already been described; this section examines research grants and student support.

Research Grants. According to Kingman, the SERC chairman, "the basic way in which research is supported is the direct research grant." In 1983, the SERC received 4602 applications for grants (up 4 percent); 2118 of these with a total value of $125,700,000 were recommended for funding. However, because of budget limitations nearly a quarter of these recommended projects in

fact were not funded; a few years ago fewer than a tenth of those recommended failed, but Kingman expects the figure to reach 30 percent soon. Grants typically are for 3 years and are used to support research assistants, travel, use of central facilities, materials and supplies, and special equipment; faculty release time and basic laboratory equipment are supposed to be provided by the universities, but this "dual support system" is severely threatened by the budget cuts received by universities in recent years. Perhaps the biggest problem facing the SERC--and this is highly correlated with its international obligations problem--is the virtual collapse of the dual support system, which means that research-grant funds must increase significantly.

Student Support. Financial constraints on the SERC have steadily reduced the numbers of students supported: 3600 in 1980-81, 3240 in 1981-82, and 3178 in 1982-83. The reductions fell primarily on postgraduate and postdoctoral awards, although the cooperative awards in science and engineering--for students working on projects jointly devised and supervised by an academic department and a business or agency--were increased from 760 to 800. Approximately 1400 postgraduate awards were made for students working on research projects, while nearly 1000 were awarded for formal postgraduate coursework. Over half of the awards were by the Science Board, and nearly 40 percent by the Engineering Board.

1/19/84

SPACE SCIENCE

ALFVÉN ON SPACE PHYSICS

by R.L. Carovillano. Dr. Carovillano is the Liaison Scientist for Space Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until June 1984 from Boston College, where he is Professor of Physics.

The Swedish physicist, Hannes Alfvén (Royal Institute of Technology, Stockholm), is one of the more accomplished and controversial scientists of the century. His research spans several fields--space and plasma physics, cosmic ray physics, astrophysics and cosmology--and his earliest publications appeared some 45 years ago. Alfvén's work includes an early theory (1939) on magnetic storms, the widely used guiding center approximation of particle motion in a magnetic field, studies of plasma wave phenomena, the book *Cosmical Electrodynamics*, studies of electric fields in a neutral plasma and the frozen flux concept, and many other topics. Much of his work was done at the Royal Institute of Technology in Stockholm and the University of California at San Diego. In 1970, Alfvén was the recipient of the Nobel prize in physics for his theories contributing to the founding principles of plasma physics.

At the 18th General Assembly of the International Union of Geomagnetism and Aeronomy--held in Hamburg, Federal Republic of Germany in August 1983--Alfvén gave a talk on the importance of space physics and its influence on the development of astrophysics. Some highlights of the talk are described below.

Space research is the extension of polar research and the study of the aurora. The auroral zone is the region where the cosmic plasma is able to penetrate into the earth's atmosphere and generate the observed optical emissions. The aurora is colorful, complex, time-dependent, and certainly difficult to understand. In many ways, space research today is the culmination of the sequence of great scientific contributions that carried from Ptolemy, to Copernicus, to Kepler, to Newton, to Einstein. In the progression of ideas, the development of new instrumental techniques has resulted in major advances. Thus, Galileo's introduction of the telescope contributed more than did the work of Copernicus to the destruction of the crystal spheres and epicycles of Ptolemy. Today, in addition to viewing the aurora or outer space at optical or visible wavelengths, scientists make observations extending over a vast span of the electromagnetic spectrum, including radio waves, infrared, ultraviolet, x-ray, gamma rays, and higher energy frequencies--thereby more than trebling the window of observation.

Modern space physics began with the first satellite launches and Van Allen's introduction of space experimentation. Hardware development and *in-situ* magnetospheric measurements have been crucial to the development of the field. Van Allen's measurements play the same role in modern space research as do Galileo's telescope and the establishment of Copernicus' theory in the break from the past.

Plasmas exist on an enormous expanse of spatial scales extending from

microscopic distances of about 10^{-6} m for laser-fusion processes to supermacroscopic distances for interstellar clouds, cosmological considerations, and ultimately the Hubble distance (about 10^{26} m). The range 10^{-1} to 10^{26} m, when divided into sequential segments in the ratio of a billion meters, is called the cosmic triple jump. The first interval, 10^{-1} to 10^{8} m extends from the scale of collisional laboratory plasmas to collisionless space plasmas on the scale of planetary magnetospheres. Only in this plasma regime have plasma experiments and *in-situ* measurements been performed. The latter includes all of the terrestrial planets, Jupiter, Saturn, and the interplanetary medium. Almost all of our understanding of plasma physics derives from study of this regime. The second interval, 10^{8} to 10^{17}m, encompasses processes such as star formation and interstellar clouds and is the principal domain of astrophysics. The final regime, 10^{17} to 10^{26} m, relates principally to galactic and cosmological considerations.

Plasma physics has developed from three independent factors: *in-situ* spacecraft measurements, laboratory plasma physics, and transfer of knowledge. The first served to discredit earlier theories of space that were not based on observations and to set the field on a proper course. The second served the usual role in the proper development of a branch of physics. The third draws upon the other two to apply knowledge gained in one area (or parameter domain) to another area that lacks empirical evidence. The extrapolation process is only starting now, and it will produce important results in the future.

Alfvén gave electric double layers, magnetic merging, and current filaments as examples of knowledge transfer. Electric double layers have been extensively studied in the magnetosphere and serve to accelerate particles to kilovolt energies. Double layers can accelerate auroral electrons to greater than 10-keV energies, and the mechanism may exist elsewhere in nature. Magnetic merging is believed to be an important magnetospheric plasma energization process and may apply to many plasma domains. Space plasmas, such as the aurora, the solar corona, and the solar surface, appear to be filamentary and not homogeneous. This property seems to apply on all scales of plasma observations from the earth to the interstellar medium. Thin regimes of stable current layers separate regions of different (often essentially oppositely directed) magnetization.

Alfvén commented on the rapid development of space physics and its dependence on *in-situ* observations. Only 100 years ago, space was believed to be completely empty. Twenty-five years ago, the situation was still nebulous. Now we know space is highly structured and complex, containing double layers, plasma boundaries, and cellular structures. Current layers such as the magnetopause could not have been discovered remotely; *in-situ* measurements were needed.

Alfvén speculated that plasma throughout the universe may have a cellular structure, with current layers separating adjacent plasma regimes. The idea would be important to cosmology. The cellular structure is suggested by the so-called pinch effect. As a plasma cloud begins to contract gravitationally, the collapse is counteracted by the electromagnetic force equation:

$$\text{grad}\ (p+B^2/2\mu_o) - (B\cdot\text{grad})\ B/\mu_o=0.$$

Here p is the plasma gas pressure, B is the magnetic field, and μ_o is the magnetic permeability. The second term in the equation can assist the pinch effect and help create the filamentary current structure. With Newton's equations, gravitational collapse tends to result in spheres. But for plasmas, Maxwell's equations also apply and tend to produce current filaments.

Space physics research has led to many discoveries in the solar system and to fundamental advances in our understanding of plasmas. Active experiments in space to be performed soon will extend our knowledge--particularly of the interaction between a neutral gas and a plasma. It is important to recognize the importance of magnetospheric research. In magnetospheric physics, direct measurements have shown earlier theories to be obsolete. By virtue of direct measurements, magnetospheric research gives us a platform from which to study all of astrophysics. Space research *experience* is crucial to the development and the clarification of the rest of astrophysics.

1/19/84

EUROPEAN ASTRONOMY MEETING

by R.L. Carovillano.

The Seventh European Regional Astronomy Meeting was held in Florence,

Italy, from 12 through 16 December 1983. More than 600 scientists attended the meeting, which had a strong US representation. Presentations included about two dozen invited talks and about 240 contributed papers.

The program had one or more sessions in each of eight sections covering areas of astronomy and astrophysics: Solar Physics; Solar System; Stars and Stellar Evolution; Interstellar Medium; Galaxies, Clusters of Galaxies, Cosmology; High Energy Astrophysics; Astronomical Techniques; and Atomic and Molecular Physics for Astronomy. Two additional, special sessions were held for the IRAS and EXOSAT satellite missions. Invited talks on a wide range of topics were given in each of the sections, which often ran dual and competing sessions. One invited talk was given each morning in a plenary session for the complete meeting. The plenary lectures were: "Optical Telescopes of the Future," by L. Woltjer (European Southern Observatory); "The Halley Comet," by J. Rahe (Bamberg); "Solar Oscillations," by E. Fossat (Nice); "Pulsars and Supernova Remnants," by F. Pacini (Florence); "The Space Telescope," by R. Giacconi (Johns Hopkins University); and "Accretion Disks," by J. Pringle (Cambridge).

Topics discussed at the meeting ranged widely into almost every area of astronomy. Coverage included not only solar physics but also a bit of planetary science, particularly atmospherics. Many papers dealt with recent, current, and future space missions. Thus, Voyager, Einstein, Cos B, Giotto, Space Telescope, and other missions were prominent in the discussions. Overall, however, the Infrared Astronomical Satellite (IRAS) stole the limelight.

IRAS was the international mission sponsored jointly by the US, the UK, and The Netherlands. The US provided the sensitive infrared (IR) telescope, The Netherlands provided the spacecraft, and the UK operated the IRAS tracking station at Chilton. IRAS completed its 10-month lifetime in November 1983, when the superfluid coolant needed to operate the IR telescope was consumed. The primary objective of IRAS was to complete an all-sky, IR survey. When the mission ended, all but 5 percent of the sky had been surveyed, most of it several times over. IRAS discovered many thousands of new sources in the sky not seen in visible observations. IRAS discoveries included the detection of solid material orbiting the star Vega, young stars, zones of star formation, the center of the Milky Way, dust orbiting in rings broadly encompassing the main asteroid belt, several new comets and asteroids, and indirect evidence for the possibility of a 10th planet in the solar system.

The meeting was organized by the European Physical Society and the International Astronomical Union, with the sponsorship of the Italian Ministry of Education--Arcetri Astrophysical Observatory, the University of Florence, and the Italian Astronomical Society.

The Italian Astronomical Society plans to publish the invited talks presented at the symposium in camera-ready form in a special issue of *Memorie della Società Astronomica Italiana.*

1/19/84

QUANTITATIVE MODELS OF THE MAGNETOSPHERE

by R.L. Carovillano.

Magnetospheric research began in 1958 with Van Allen's first satellite experiment, which detected charged particles trapped in the earth's magnetic field. Hundreds of satellites have now explored the earth's magnetosphere, and vast amounts of data have been assembled that involve a large number of physical parameters. The magnetic field and plasma distribution in the magnetosphere are highly complex and are affected by many time-dependent and pseudostationary processes. Our understanding of the earth's magnetosphere has progressed far beyond the search and discovery phase that applies to the other planets. Current and planned space missions dealing with the earth's magnetosphere are designed to investigate specific physical questions or processes, such as the degree of hemispheric conjugacy of auroral processes and the detection of a plasma regime experiencing magnetic reconnection.

Because of the complexity of the phenomena involved, a theoretical understanding of magnetospheric processes and events is often partial at best. As a result, an important output from data analysis is the preparation or development of physical models. Models are of all types, but many are designed to give a limited but logical representation of "normal" magnetospheric conditions with respect to which variations and perturbations can be accurately described. The development of such models has become an important and continuing activity in magnetospheric physics. Successive generations of

certain models now exist, each generation being more comprehensive and sophisticated than the previous one. The usefulness of the models is at least twofold: to assist the data analyst in organizing a great deal of data into a comprehensive form, and to assist the development of a fundamental theory of the magnetosphere or of a magnetospheric process.

A state-of-the-art workshop on Quantitative Magnetospheric Models was held during the August 1983 meeting of the International Association of Geophysics and Aeronomy (IAGA) in Hamburg, Federal Republic of Germany. About 40 scientists attended the workshop, including leading modelers and model users. The meeting was organized and chaired by W.P. Olson (McDonnell Douglas Astronautics Co., CA). The business of the meeting included discussion of establishing a newsletter, identification of topics for sessions at future IAGA meetings, brief presentations on new or current models, and observations on the state of the field.

Most models are representations of the geomagnetic field above the surface of the earth. A quantitative model is a mathematical representation that reproduces observed magnetic field values and the field's dependence on physical variables in a specified region of the magnetosphere. The model is usually defined by input currents with a specified functional form and free parameters that are determined by numerical best-fits to the underlying data. Model inputs normally include the earth's dipole field with specified tilt angle and at least three magnetospheric current systems (or equivalent information): the magnetospause (Chapman-Ferraro) currents that confine the geomagnetic field, the dawn-dusk geomagnetic tail currents, and the magnetospheric ring current.

Quantitative models can be used for a baseline in magnetometer measurements made in space, for particle trajectory calculations, and for field line mapping, particularly to determine magnetic conjugacy at high latitudes or to determine the footprint of a spacecraft on the earth. Various other models that involve plasma processes often explicitly use the quantitative magnetic field model as an input in order to reduce the size and render computationally manageable the modeling task.

Newsletter

The discussion affirmed the need for a newsletter to collect information on the increasing number of quantitative models that now exist throughout the world. For representations of the geomagnetic field, the following information was suggested for each model described in the newsletter:

- Physical assumptions
- Validity conditions
- Model parameters
- Dipole tilt effects
- Underlying data sets
- Literature references for the model
- How to obtain the model.

Several at the meeting advocated that an archive be created for quantitative models. H. Garrett (Jet Propulsion Laboratory, CA) recommended that a book be developed on the definition and use of quantitative models. The book might be the output of a special topics conference. M.S. Gussenhaven Shea (Air Force Geophysics Laboratory, MA) pointed out the need for model users to know the regions of high reliability and of large error. Documentation of models should include this information.

Descriptions of Models

Several models were formally presented at the workshop, and two others were mentioned on several occasions.

Olson discussed the latest version of the so-called Olson-Pfitzer model of the geomagnetic field. This model is widely used by many scientists. In the latest efforts, time-dependent magnetic fields are represented. The analysis is made with the magnetic vector potential $\underline{A}$ and includes the electric field $\underline{E}$ induced by the time variation of the magnetic field, $\underline{B}$. Because the orthogonality condition $\underline{E} \cdot \underline{B} \neq 0$ is imposed, electric fields parallel to $\underline{B}$ are excluded. The plasma response to the electric field is calculated. The model requires a static distribution of charge along magnetic field lines. Preliminary results seem to be satisfactory in the plasma sheet but not at greater distances (i.e., higher L-values).

G.-H. Voigt described his model of the geomagnetic field (Voigt, 1981). Input parameters of the model include the solar wind pressure, the tilt of the dipole axis, the disturbance field of the ring current (Dst), the position of the inner edge of the plasma sheet, and the ratio of the plasma thermal pressure to the magnetic field pressure at the same inner edge. The following are restrictions or limitations on the model: the magnetopause shape is given, the magnetotail does not flare beyond 10 earth radii, the thermal pressure is taken to be isotropic, and the equatorial ring current is self-consistent but

axisymmetric--thereby neglecting day-night variations. The following are advantages of the model: it interconnects the interplanetary magnetic field and the magnetosphere; tail currents are a result of the model and not an input; a parametric representation of time dependence is given in terms of different static model states; and the force balance condition, $\underline{J}\times\underline{B}$ = grad p, where $\underline{J}$ is the current density and p the pressure, is approximately satisfied. The condition is required for equilibrium states without convection.

J. Lemaire (Institute of Space Aeronomy, Belgium) described his user-friendly model of plasma motion in the equatorial plane. Both electric and magnetic field models are inputs in the procedure. Convection due to the electric field and the effects of interchange motions on the modification of the plasmapause are included. The plasmapause is taken to be the boundary at which gravity is balanced by the interchange effect, including the centrifugal force. Because of a finite electrical conductivity, plasma drift paths cross stream lines in an effect similar to a bubble rising against gravity in a viscous fluid. The calculated plasmapause location depends on the electric and magnetic field models used. The interchange motion is always toward the zone where the sum of the gravitational plus centrifugal forces is minimum. Applications are made to whistlers and effects depending on plasmapause location as a function of geomagnetic activity.

J.G. Luhmann of the University of California at Los Angeles (UCLA) discussed her work on the magnetosheath using the gas dynamics approach developed by Spreiter and Stahara. The Hedgecock model is used to represent the field internal to the magnetosphere because it is accurate in the region of the polar cusps. The magnetosheath field is then derived using the frozen field assumption in the gas dynamic flow of the solar wind about the Hedgecock magnetopause. Variables in the model are the spatial sizes, the obstacle shape, the Mach number of the flow, the ratio of specific heats (γ), and the interplanetary field. An interesting application was the determination of likely zones of magnetic merging, namely the regions at the magnetopause where the interplanetary and magnetospheric fields were antiparallel.

J.C. Kosik (Division Mathematiques, Centre National d'Études Spatiales, France) described his model of the geomagnetic field. In this approach, the disturbance field $\underline{b}$, defined by $\underline{b} = \underline{B} - \underline{B}_D$ is modeled. Here $\underline{B}$ is the observed physical field at points in space, and $\underline{B}_D$ is the ideal dipole field. The representation of the model is analytical in terms of two scalar functions. An advantage is that the Maxwell field equation, div $\underline{B}$ = 0, is satisfied exactly. Surfaces of constant magnetic intensity are easily gotten from the model. In its present form, the model is not accurate beyond about 10 earth radii.

Useful reviews and comments on quantitative models are given by Walker (1976 and 1979) and Walker and Southwood (1982). Several at the workshop referred to the three-dimensional model of C. Michel (Rice University, TX) that includes an extended magnetic tail. Other discussion referred to the magnetic field model by N.A. Tsyganenko and A.V. Usmanov (Leningrad University) that has been developed into a user-friendly form by D. Stern (Goddard Space Flight Center, National Aeronautics and Space Administration [NASA], MD).

Comments and Observations

The main purpose of the workshop was to promote activity, communication, and exchanges of information on methods in the field and the status of models. Olson stated that the availability of a magnetic field model that would serve as the reference for the scientific community was a remote goal.

There was considerable discussion about whether future workshops in quantitative models should have an enlarged scope. Currently, the only quantitative magnetospheric models are of the geomagnetic field. The enlarged scope could include, for example, analytical representations of statistical data, certain stationary state models, and certain time-dependent models. C. Russell (UCLA) suggested that the working group develop a statement on future needs for models and what is lacking in current models.

Voigt stated that an important deficiency of present models is that the geomagnetic tail is an *ad hoc* input rather than an output of the model. M. Sugiura (Goddard Space Flight Center, NASA, MD) pointed out that an analytical representation of the magnetic field, including effects of field-aligned currents, does not exist. Also, models have to be adjusted in time for certain effects. For example, the "ground state"--the lowest energy state possible--of the magnetosphere has probably changed by 15 gammas from 1960 to 1980. In this regard, discussion emphasized

that the equivalence of the ground state and the quiet-time magnetosphere was still an open question.

Regarding future meetings, R. Carovillano (US Office of Naval Research, London) suggested that quantitative models of electric fields be included. Russell commented that the dependence of magnetospheric currents on solar wind conditions also be included. Models should attempt to quantify the intensity and location of current systems as a function of magnetospheric or solar wind parameters, particularly in distinguishing between quiet and active conditions. H. Radoski (Air Force Office of Scientific Research, Washington, DC) pointed out that current models would evolve toward full magnetohydrodynamic (MHD) efforts, and that MHD models which attempt to include solar wind, magnetosheath and magnetospheric interactions should be included in future meetings. The working group agreed that such suggestions should be incorporated into a session at the next IAGA meeting, to be held in 1985 in Prague.

Three independent efforts--quantitative modeling, MHD modeling, and computer simulations--currently involve essentially independent scientific communities. The work and output of these communities will tend to merge in the future. R. Wolf (Rice University, TX), whose group has developed the leading MHD model, commented that present MHD models are not user friendly and probably will not be for some time. It might be necessary to develop a different kind of MHD model with user convenience in mind. Although significant progress has taken place in computer simulation efforts, the field is confronted with significant practical and physical difficulties. Practical difficulties include computer size, user cost, and availability. Physical difficulties include the use of proper boundary conditions and the inclusion of operative physical effects in different plasma regimes.

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1/24/84

NEWS & NOTES

UK LAB DEVELOPS NEW RECHARGEABLE BATTERY

A completely new type of rechargeable battery is being developed at the UK Atomic Energy Authority's Harwell Laboratory, according to *The Times* (London), 18 December 1983. On a weight-for-weight basis, the device can store 10 times as much energy as a conventional lead-acid battery.

The Times notes that eight to 10 encyclopedia-sized battery modules would be enough to power a small electric car such as the Volkswagen Golf, which already exists in an electric version. Batteries that are lighter and more compact than the lead-acid type are said to be the key to the successful development of electric vehicles.

A basic cell of the Harwell battery consists of three flexible films with a total thickness of only 0.1 mm; the arrangement delivers 2.4 V. For higher voltages, the cells can be stacked together like the pages of a book. Capacity is increased by using bigger areas of film. To save space, the battery elements can be wound up like the layers of dough and jelly in a breakfast roll (Figure 1).

The Harwell battery's design is novel because the electrolyte is a thin film of a special polymer rather than a liquid, as in a lead-acid battery. This development makes possible the all-solid, thin-film construction. One of the other two films contains lithium, and another is made of a complex mixture on a backing of nickel foil.

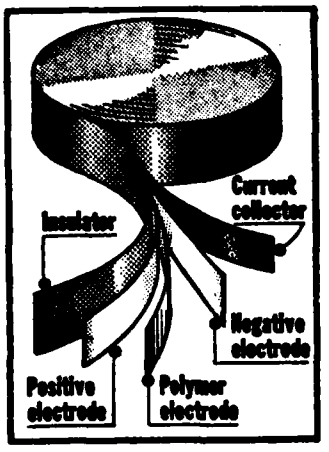


Figure 1. Rolled version of Harwell battery (adapted from *The Times* graphic by Gordon Beckett).

The battery now has to be heated to 100°C to operate efficiently. The main task remaining for the Harwell Laboratory is to reduce this to room temperature.

L.E. Shaffer
1/25/84

NEW JOURNAL ON GRAVITY

Classical and Quantum Gravity is the title of a new bi-monthly journal published by the Institute of Physics in London. The first issue appeared in January 1984. The journal is intended to provide a forum for theoretical physicists, mathematicians, and cosmologists.

Articles accepted for publication will have been refereed and will reflect current research in all branches of the theory of space-time and gravitation. Areas of publication will include classical theories of gravity, global properties of space-time, classical general relativity, quantum field theory in curved space, early universe studies, supergravity, and quantum gravity.

The editor is Dr. M.A.H. MacCallum (Queen Mary College, London), with an editorial board consisting of Prof. J. Ehlers (Max-Planck-Institute for Physics and Astrophysics, Garching), Prof. J.B. Hartle (University of California, Santa Barbara), Prof. C.J. Isham (Imperial College, London), Dr. S.T.C. Siklos (University of Cambridge, UK), Dr. K.S. Stelle (Imperial College, London), Dr. P. Tod (University of Oxford, UK), and Prof. P. van Nieuwenhuizen (State University of New York, Stony Brook).

In addition to the refereed articles, short contributions such as comments and addenda, occasional solicited review articles, book reviews, meeting announcements, and conference reports will be published.

The subscription cost is $85 for the first year (six issues), and US inquiries may be sent to the American Institute of Physics, Marketing Services, 335 East 45 Street, New York, NY 10017. A free specimen copy of the journal should be available upon request. Other inquiries and contributions should be addressed to: The Managing Editor, Classical and Quantum Gravity, The Institute of Physics, Techno House, Redcliffe Way, Bristol BS1 6NX, England.

R.L. Carovillano
1/24/84

NEW EUROPEAN COMMUNICATIONS MAGAZINE LAUNCHED

The first issue of *Cable and Satellite Europe* was released in January 1984. The magazine will be published monthly in London and is available at the annual subscription rate of $70. The staff includes Jamie Jauncey (publisher), Colin McGhee (editor-in-chief), Jim Hutchon (technical editor), a reporter, two specialist correspondents, and overseas correspondents assigned to France, Belgium, The Netherlands, Scandinavia, the Federal Republic of Germany, Japan, and the US. The magazine was started to respond to the effects of the communications revolution in Europe and other parts of the world. The degree of emphasis on the importance of the European communications community is perhaps reflected in the comment by McGhee, who said, "Certainly, America and Japan rival Europe in the development of cable and satellite technology, but those countries lack the diversity of Europe."

Technological advances, industrial interests and developments, political and legal issues, copyright questions, paneuropean advertising standards, satellite broadcasting across national borders, pay TV, and other activities and developments affecting communications will be reported in the magazine. Seven guest contributors have been named to write for the publication, presumably on a regular basis. Plans include developing an extensive computer database of the communications industry and making the assembled information available to decision makers throughout the world.

For subscriptions or other information, write to:

Cable & Satellite Europe
533 Kings Road
London SW10 0TZ
ENGLAND

The first issue of the magazine is available with the compliments of the publisher.

R.L. Carovillano
1/19/84

YET ANOTHER NEW JOURNAL

Elsevier Science Publishers of Amsterdam has announced the pending publication of the *Journal of Controlled*

Release. This journal is to be the official organ of the Controlled Release Society (CRS), an organization formed in 1978.

According to the announcement from Elsevier, the new journal will be an international one dealing with the science and technology of the controlled release of active agents. CRS and Elsevier use the term "controlled release" in its broadest sense, and the journal will accept papers dealing with control over rate of release using--either singly or in combination--diffusion, chemical reactions, dissolution, osmosis or mechanical devices, as well as control over the site of action of the active agent using pro-drugs or carriers such as water-soluble polymers, microcapsules, or liposomes. Controlled release topics are not limited to human or animal therapeutic agents but will cover those dealing with insect and other pest management, fertilizers, weed control, and marine antifouling applications.

The journal, intended to serve a wide range of specialists, will also feature relevant research dealing with toxicology, pharmacokinetics, and biocompatibility.

In addition to original papers, technical reviews, and short communications, the journal will include book reviews, reports of meetings, descriptions of new controlled release products, announcements pertaining to activities of CRS, and other announcements. The editors of the journal are Jorge Heller (SRI International, Menlo Park, CA) and Jan Feijen (Twente University of Technology, Enschede, The Netherlands).

Thomas C. Rozzell
1/25/84

MAGNETOSPHERIC PHYSICS CONFERENCE EMPHASIZES RUSSIAN-FRENCH COLLABORATIONS

An international conference will be held in Toulouse, France, from 15 through 18 May 1984 on the results of the ARCAD 3 project and recent programs in magnetospheric and ionospheric physics. The conference is sponsored by the French and will emphasize ARCAD 3 results, which will be compared with those of other recent satellite missions.

The French-Soviet collaborative space efforts include manned and unmanned projects. ARCAD 3 is a joint scientific effort for the study of magnetospheric, auroral, and i phenomena aboard the AUREOL 3 The satellite was launched by into a high-latitude orbit on ber 1981. ARCAD 3 experiments space measurements of particl tric fields, magnetic fields, phenomena. Results of these ments will be presented at th ence. Presentations are als for comparative studies of results with results from t radar facility and from satell as Dynamics Explorer, ISEE, an

For further information, c

Centre National d'Études Spati
Département des Affaires Unive
18 Avenue Edouard-Belin
31055 Toulouse Cedex, FRANCE

R.L. Carovillano
1/18/84

NORWAY WORKSHOP ON THE POLAR C

A North Atlantic Treaty tion Advanced Research Worksh Morphology and Dynamics of Cusp will be held in Norwa through 11 May 1984. The purp *workshop is to assemble exper* field to discuss relevant m observations to clarify physic ties of the cusp and its role terrestrial coupling processes based and satellite observatio utilized.

Eight scientific sess planned:

- Mass transfer in the cusp r electrodynamic coupling ionosphere
- Ionosphere-atmosphere coupl
- Currents and magnetic pertu
- Particle precipitation in cusp
- Optical emissions
- Electric fields, waves, a lence
- Radiowave probing of the po
- Comparison of ground, ro satellite observations in t

The final session will include sion of future cusp experi their coordination, and a summ workshop with recommendation distinguished scientists h engaged as session leader discussants, and invited speak

Attendance at the workshop will be limited to about 50 participants. Applicants will be selected by a scientific program committee headed by Prof. A. Egeland of the University of Oslo on the basis of their active interest in the field. For further information, contact:

Mrs. A.-S. Andresen
Institute of Physics
University of Oslo
P.O. Box 1038, Blindern
Oslo 3, NORWAY

R.L. Carovillano
1/18/84

NATO ADVANCED STUDY INSTITUTE ON ADVANCES IN COGNITION AND MOTIVATION

The North Atlantic Treaty Organization (NATO) plans to sponsor an advanced study institute to examine recent advances in research on cognition, motivation, and their interaction. As with previous NATO-sponsored meetings of this type, the aim is to assemble a staff of leading researchers who can in turn provide advice and instruction to young researchers in the field. A tentative list of staff members for the institute includes Profs. John Carroll, University of North Carolina; Hans Eysenck, University of London; Heinz Heckhausen and Frans Weinert, Max-Planck-Institute for Psychological Research, Munich; Douglas Jackson, University of Western Ontario; Richard Snow, Stanford University and ONR, London; and Robert Sternberg, Yale University. The meeting will be held in Nice, France, in mid-December 1984. In charge of planning is Prof. Sid Irvine, Department of Psychology, Plymouth Polytechnic, Plymouth, UK, from whom application information can be obtained.

Richard E. Snow
1/26/84

NATO CONFERENCE ON MOTIVATION AND MORALE

On 28 through 30 May 1984, the North Atlantic Treaty Organization (NATO) will sponsor a conference on motivation and morale, with particular reference to the current research of military psychologists working in components of the NATO forces. Invited speakers include Profs. Heinz Heckhausen of the Max-Planck-Institute for Psychological Research, Munich; Irwin Sarason, University of Washington; and Lee Sechrest, University of Michigan. The conference will be held at NATO headquarters in Brussels. For further information, contact the Chair of the Planning Committee, Dr. Friedrich W. Steege, Deputy Chief, Psychological Service of the Federal Armed Forces, Ministry of Defense/Pll4, Postfach 1328, D-5300 Bonn 1, Federal Republic of Germany.

Richard E. Snow
1/26/84

ONRL STAFF CHANGE

In April we welcomed aboard a new liaison scientist, Dr. Kenneth D. Challenger, Associate Professor of Mechanical Engineering, Naval Postgraduate School, Monterey, CA. His field is materials science.

ONRL COSPONSORED CONFERENCES

ONR, London, can nominate two registration-free participants in the conferences it supports. Readers who are interested in attending a conference should write to the Scientific Director, ONRL, Box 39, FPO New York 09510.

Third International Symposium on Halide Glasses, Université de Rennes, Rennes Cedex, France, 24-28 June 1984.

International Conference on Laser Processing and Diagnostics--Applications in Electronic Materials, Linz, Austria, 15-19 July 1984.

Tenth General Assembly of the European Geophysical Society, Louvain-la-Neuve, Belgium, 30 July - 4 August 1984.

Fatigue '84, Birmingham, UK, 3-7 September 1984.

International Conference on Digital Signal Processing, Florence, Italy, 4-8 September 1984.

Surface Modification of Metals by Ion Beams, University of Heidelberg, Federal Republic of Germany, 17-21 September 1984.

Ninth European Specialist Workshop on Active Microwave Semiconductor Devices, Veldhoven, The Netherlands, 10-12 October 1984.

SCIENCE NEWSBRIEF FOR JANUARY

The following issue of *Science Newsbrief* was published by the ONR, London, Scientific Liaison Division during January. *Science Newsbrief* provides concise accounts of scientific developments or science policy in Europe and the Middle East. Please request copies, by number, from ONR, London.

Science Newsbrief Number	Title
2-1-84	Phospholipid Polymers Form Basis for New Biocompatible Material, by Thomas C. Rozzell.

JANUARY MAS BULLETINS

The following *Military Applications Summary (MAS) Bulletins* were published by the ONR, London, Military Applications Division during January. The *MAS Bulletin* is an account of naval developments in European research, development, test, and evaluation. Its distribution is limited to offices with the US Department of Defense. DoD organizations should request copies of the *Bulletins*, by number, from ONR, London.

MASB Number	Title
1-84	Esvagt 5 Rescue and Personnel Transfer Basket
2-84	Secure Fiber Optic Data Transmission
3-84	FEFA--Future European Fighter Aircraft--A Five-Nation All-European Fighter?

ONRL REPORTS

To request reports, check the boxes on the self-addressed mailer and return it to ONR, London.

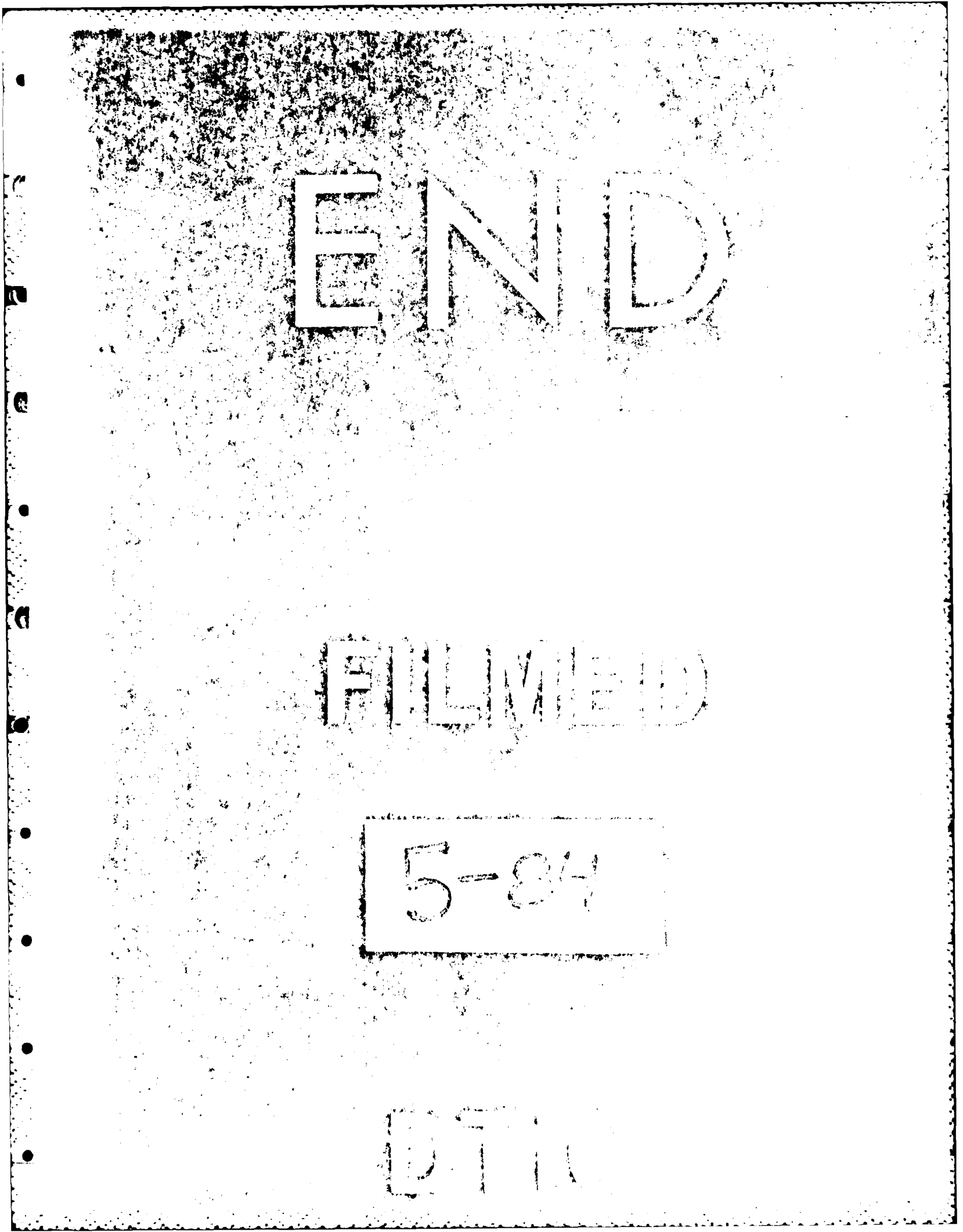
C-18-83: *Fast Electrical and Optical Diagnostic Principles and Techniques: A NATO Advanced Study Institute*, by M. Frank Rose. The institute was divided into the following major sections: (1) overview of applications and needs, (2) voltage and current measurements, (3) data acquisition, (4) grounding and shielding, (5) fast photography, (6) refractive index measurements, (7) X-ray diagnostics, (8) spectroscopy, and (9) active optical techniques. The report examines these topics and provides tables comparing various nanosecond instrumentation techniques.

R-8-83: *Armament Acquisition by the French Ministry of Defense*, edited by Larry E. Shaffer. This report discusses the responsibilities and organization of France's Delegue General Pour l'Armement. The DGA guides the Ministry of Defense's acquisition policy.

R-1-84: *Bibliography of the Research Staff of the UK Institute of Oceanographic Sciences, Bidston Observatory (1979-83)*, by Robert Dolan. This report provides an up-to-date listing of IOS Bidston's publications, many of which are in journals and report series that are not routinely available to oceanographers in North America.

EUROPEAN VISITORS TO THE US SPONSORED BY ONR, LONDON

Visitor	Areas of Interest	Organizations to be Visited	Want Information? Contact at ONRL
Dr. C.A. Brookes Dept. of Engr. Science University of Exeter North Park Road Exeter, Devon, EX4 4QF	Engineering Science/ Hardness Testing	Naval Research Laboratory NSWC Whiteoak, MD (9-20 July 84)	James W. Daniel
Dr. Norman Louat University of Oxford Dept. of Metallurgy & Materials Science Parks Road Oxford OX1 3PH	Materials Science/ Dislocation Theory	Naval Research Laboratory (Jan.-April 84) temporary research appointment	James W. Daniel
Prof. David Tabor Univ. of Cambridge Cavendish Laboratory Madingley Road Cambridge CB3 0HE	Physics/Friction & Wear	ONR HQ Naval Research Laboratory NSWC (9-20 July 84)	James W. Daniel
Dr. T.P. Obrenovitch CERB. HIA, Sainte Anne F-83800, Toulon Naval France	Hyperbaric Physiology	Beth Israel Medical Cen., NY (21 May 84) Univ. of Penn. Medical Center (22-23 May 84) Natl. Inst. of Health, Bethesda, MD (24 May 84) Uniformed Serv. Univ. of the Health Sciences Bethesda, MD (25-26 May 84) Gerontology Research Center Baltimore, MD (27 May 84) George Washington Univ. Med. School Washington, DC (28 May 84)	T. C. Rozzell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